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Development of a smart mobile garden robot for supervising greenhouses

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# ملخص

تستدعي التقنيات الحديثة في حياتنا اليومية وفي العديد من المناطق ، مما يثير الدهشة في بعض الأحيان. رؤيتنا هي جيل جديد من الأنظمة الآلية والذكية المستقلة والمرنة والمتوافقة والمترابطة التي تعمل بسلاسة مع زملائهم في العمل البشري في المزارع ومصانع المواد الغذائية. ومع مساعدة تقنيات الحوسبة السحابية حتى نتمكن من توفير القدرة على مراقبة عدد مهم من البيوت الزجاجية الحساسة والإشراف عليها والتحكم فيها ، يجب على المزارعين دون الحاجة إلى التدخل الجسدي في كل مرة لاتخاذ إجراءات منتظمة.

Abstract

New technologies are inviting in our daily lives and in many areas, sometimes very surprising. Our vision is a new generation of smart, flexible, robust, compliant, interconnected robotic and autonomous systems working seamlessly alongside their human co-workers in farms and food factories. And with the help of the Cloud Computing technologies so we can offer the ability to monitor, supervise and control an important number of normal and sensitive greenhouses to the farmers without the need to physically intervene each time to make regular actions.

Résumé

Les nouvelles technologies sont invitantes dans notre vie quotidienne et dans de nombreux domaines, parfois même très surprenantes. Notre vision est une nouvelle génération de systèmes robotiques et autonomes interconnectés, intelligents, flexibles, robustes, compatibles et fonctionnant en toute transparence aux côtés de leurs collaborateurs humains dans les exploitations agricoles et les usines agroalimentaires. Et avec l'aide des technologies de Cloud Computing, nous pouvons offrir la possibilité de surveiller, superviser et contrôler un nombre important de serres sensibles aux agriculteurs sans avoir à intervenir physiquement à chaque fois pour effectuer des actions régulières.

Acknowledgement

First, I would like to thank the Almighty God for granting me life and good health as well as supreme protection and guidance throughout my studies.

I am thankful to my supervisor, Dr.Soheyb AYAD, for his informative and useful guidance and suggestions throughout the journey for project design.

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Summaries

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General Introduction

In 2015, the UN 2030 sustainable development agenda and international community committed itself to ending hunger (Transforming Our World: The 2030 Agenda for Sustainable Development). How close are we to reaching the objective? The short answer: Not close at all roughly 800 million people worldwide suffer from hunger. And under a business as usual scenario, 8 percent of the world's population (or 650 million) will still be undernourished by 2030.

Although demand is continuously growing, by 2050 we will need to produce 70 percent more food. Meanwhile, agriculture's share of global GDP has shrunk to just 3 percent, one-third its contribution just decades ago. The reality is that very little innovation has taken place in the industry of late—in any case, nothing to indicate that food scarcity and hunger will not be an issue in the coming decades. The world needs drastic change: following the current path will not solve the problem.

Four main developments are placing pressure on the legacy agriculture model in meeting the demands of the future: demographics, scarcity of natural resources, climate change, and food waste are all intensifying the hunger and food scarcity problem.

To meet these challenges will require a concerted effort by governments, investors, and innovative agricultural technologies. It can be done, but we need to disrupt the system.

Agriculture 4.0 will no longer depend on applying water, fertilizers, and pesticides uniformly across entire fields. Instead, farmers will use the minimum quantities required and target very specific areas. It will be possible to grow crops in arid areas, making use of abundant and clean resources such as the sun and seawater. Other innovations—3D printing of foods, cultured meat, genetic modification, and seawater agriculture—are still in the early stages but could all be game changers in the next decade.

Farms and agricultural operations will have to be run very differently, primarily due to advancements in technology such as sensors, devices, machines, and information technology. Future agriculture will use sophisticated technologies such as robots, temperature and moisture sensors, aerial images, and GPS technology. These advanced devices and precision agriculture and robotic systems will allow farms to be more profitable, efficient, safe, and environmentally friendly.[1]

Our goal is to use IoT and cloud computing and robotic to solve the monitoring problem, and minimize total energy costs and demand costs while taking into accounts the important parameters of greenhouses; in particular, indoor temperature and humidity and lighting levels must be kept within acceptable limits.

This memory is organized in four chapters. In the first chapter, we will discuss smart farming in introducing information technology and agriculture intelligent and it challenges. The second chapter we will know more and IoT and robotic plus some of the related work we have studied. The third chapter contains the design of our system and a number of diagrams explaining the functionality of the robot and the greenhouse monitoring system. The fourth chapter is to present the list of development tools and programming language used to develop our project, the monitoringdashboard.

Chapter 01

Chapter 1

Smart Agriculture

1.1 Introduction

Agriculture plays a significant role for economic and social development in most undeveloped countries. Reasons for this include issues of food security and health of people, requirement for increasing yields and food quality improvement. Challenges in agricultural development of every country are great like fulfillment of increasing demand for food. The agricultural sector is influenced by global factors and fast changes. These facts indicate that there is great need for information and information technologies (IT), which can be used to cope with the challenges and changes and to improve agricultural production and marketing. [2]

In this chapter, we will first present the use of information technology in the agricultural sector to illustrate the impact of information and communication technologies and IoT on smart agriculture and it architecture.

1.2 Smart agriculture

Between now and 2050, the world's population will increase by one-third. Most of these additional 2 billion people will live in developing countries. At the same time, more people will be living in cities. If current income and consumption growth trends continue, FAO estimates that agricultural production will have to increase by60 percent by 2050 to satisfy the expected demands for food and feed. Agriculture must therefore transform itself if it is to feed a growing global population and provide the basis for economic growth and poverty reduction. [3]

1.2.1 Defining smart agriculture

Smart Agriculture could be defined as “an approach to understand the basic requirements as well as the changes in current environment due to external factors based on the context information and utilization of collected data to optimize sensors’ operation or influence the operations of actuators to change the current environment.[4]

1.2.2 The concept of smart agriculture

The concept of smart agriculture is based on integration of three well known technologies that are Sensor Network technology, Grid Computing technology and Context-aware Computing technology. [4]

Smart Agriculture is based on the following steps:

- Sensing local agricultural parameters
- Identification of sensing location and data gathering
- Transferring data from crop field to control station for decision making
- Decision making based on local data, domain knowledge and history
- Actuation and Control based on decision

It is obvious that the optimization of sensors’ operations will be towards the better development of the crop or plant. [4]

The smart agriculture process is supported by the sensor network technology as it requires sensing and communication.

Grid computing technology supports in providing the low cost high power computing and distributed data storage facility. This is extreme need as sensor network generates huge amount of sensed data that requires heavy amount of storage space as well as the high computing power for processing and decision making procedures. The use of grid computing also supports the cause of low cost solution development. The next step of the process involves grid computing facility and the context-aware computing facility.

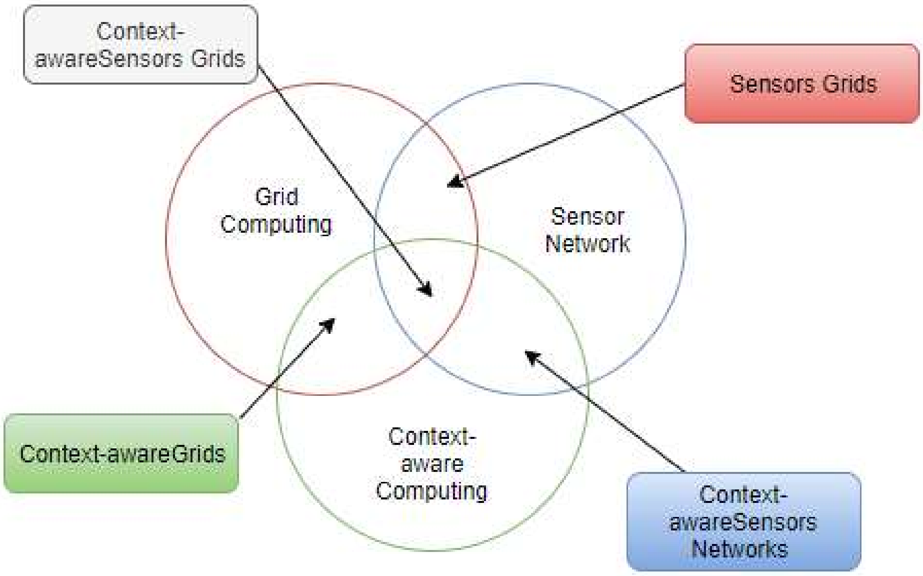


Figure 1 Technology Integration

Context-aware computing is an aid to model the exact situation based on the sensed data. Context-awareness supports the decision making process to formulate the aroused problem and its solution based on the current and history data considering their relationship with the problem. [4]

1.3 Information and Communication Technologies (ICTs)

ICTs are any devices, tools that permit the exchange or collection of data through interaction or transmission. ICT is an umbrella term that includes radio, television, mobile phone, internet, electronic money transfer, etc. **[5]**

Figure 2 ICTs in Agrivulture

1.3.1 Using information technology in the agriculture

Wisdom Agriculture, as it is known in China, is the holistic application of information and communications technology (ICT) to agriculture. This means taking full advantage of modern information technology achievements including computers and networks, internet of things, cloud computing, 3S technology (Remote sensing, Geographic information systems, GPS), and wireless communication technology in order to develop agriculture.

Using these technologies can provide farmers, policy makers and development organizations with information that is more complete thanks to improved remote sensing, more detailed data, better communication tools, intelligent control of agricultural production and management and a better provision of public services to agriculture. This carries huge potential for making farmers produce more and better food all while making them better off economically and improving food security and nutrition. [6]

ICT applications can make a significant contribution to meet this future global food needs. Information and Communication Technology can do so by collecting and sharing timely and accurate information on weather, inputs, markets, and prices; by feeding information into research and development initiatives; by disseminating knowledge to farmers; by connecting producers and consumers, and through many other avenues. Some of the broad areas where ICT plays a crucial role in agriculture are shown above. [7]

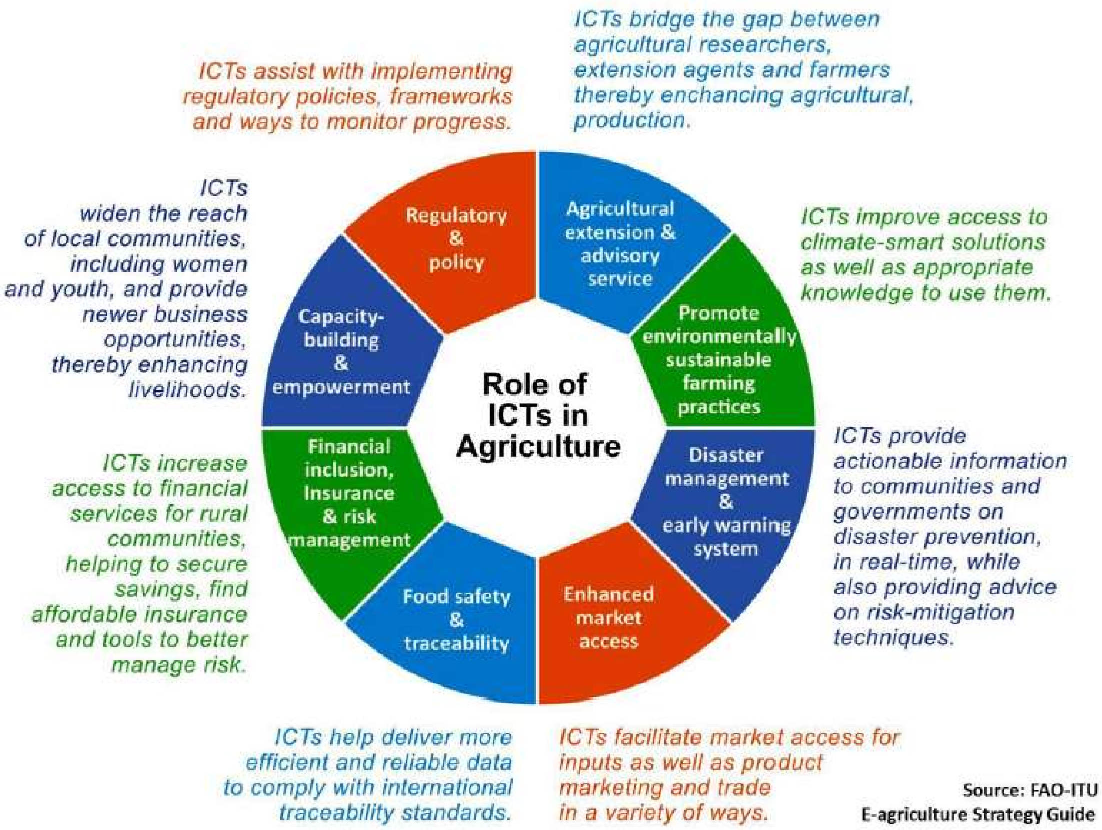


Figure 3The role of ICT in agriculture

The increase in the use of digital technologies has created benefits for all through easier communication and information sharing, and improving social connectedness. Inclusion, efficiency, and innovation are the main mechanisms for digital technologies to promote development. Nearly 70 percent the population in developing countries own a mobile phone. The number of internet users has more than tripled in a decade, from 1 billion in 2005 to an estimated 3.2 billion at the end of 2015. [7]

1.3.1.1 Improving market access

In agriculture, ICTs can bring significant benefits through better information on markets. Prices signal opportunities to producers, consumers, and traders — such as when excess demand is creating more profitable opportunities to sell or when excess supply leads to cheaper deals. They also reflect changing consumption patterns and contain information that can be used by farmers when they decide what and how much to produce. With increased access to mobile phones, farmers can better plan production and investments, based on supply-and-demand fundamentals, thus increasing market efficiency.

Indeed, facilitating market access through the provision of information on prices is the most frequent ICT application on agriculture. [3]

1.3.1.2 Agricultural extension and advisory services

Traditional extension services face several challenges in developing countries that limit their efficiency. Poor infrastructure makes it harder and more costly to visit remote areas. For this reason, often extension programmers provide only one-time information to farmers, lessening their long-term impact. In addition, traditional extension is plagued by principal-agent and institutional problems, including a lack of accountability. [8]

ICTs can increase smallholder's access to timely extension information while addressing many of these challenges by reducing the cost of extension visits, enabling more frequent two-way communication between farmers and agents, and improving agents' accountability. ICTs also enhance access to private information from social networks, thus facilitating learning from one's peers, which is crucial for technology adoption. By increasing communication linkages between farmers, extension agents, and research centers, ICTs can improve the flow of relevant information among all these agents. [7]

1.3.1.3 Climate change adaptation and early warning

The effects of climate change are already impacting agriculture, making the challenge of achieving food security and improving nutrition increasingly difficult. In the face of such challenges, information is the main to preparedness; for farmers, this could mean the difference between a successful and a failed harvest. ICT-based tools related to climate change issues and early warning can assist in reducing the risks faced by smallholders.

At the micro level, the provision of timely updates on local meteorological conditions can push out early warning messages related to extreme weather events – such as possible flooding, for instance. For example, *Africa Adapt*, in Senegal, facilitates vulnerable communities' access to information on climate change adaptation from researchers, policymakers and civil society organizations. It acts as a community of practice, and is supported by a website where members can share updates on face-to-face meetings about their work and adaptation techniques.

At the macro level, the World Food Studies (WOFOST) simulation model, developed by the Centre for World Food Studies (CFWS) in cooperation with the University of Wageningen, analyzes growth and production levels of annual crops and serves to calculate production levels for crops based on soil and weather conditions, among other factors. [9]

1.3.1.4 Food safety, traceability and certification

Food borne illnesses pose a serious health threat to the world population. Increasingly, food traceability has become very important as a risk-management tool, by which the movement of food can be followed through specified stages of production, processing, and distribution, thereby improving customer confidence. Traceability of livestock also ensures that animal disease monitored and controlled more effectively, thereby facilitating regional and international trade. For example, an internet based electronic service, TraceNet, facilitates certification for export of organic products from India. It collects stores and reports, forward and backward traces quality assurance data. [7]

1.3.1.5 Financial inclusion

Transfers and payments, credit, savings, and insurance are examples of financial services that are offered through ICTs. ICTs can significantly help improve rural communities' access by providing financial institutions the means to enter rural markets through unconventional methods through a reduced need for high-cost branches and improved productivity of the staff in place.

M-PESA enables urban Kenyans to send money home easily to their families in rural areas. Since its beginning, it has expanded significantly into other services, such as savings, and new clients, such as businesses. ICTs play a significant role in increasing access to credit by smallholders but also in facilitating the well-functioning and efficiency of the credit market, especially by reducing information and monitoring costs. Like DrumNet in Kenya, ICT platforms can link farmers with formal lenders (such as banks and microfinance institutions) but also informal ones (such as input suppliers and food processors or traders), and provide improved (credit) risk monitoring.

Smallholders lack access to formal banking services. Informal institutions, such as village savings.[7]

1.4 Platforms and programs of ICT applications in agriculture

1.4.1 E-Agriculture Community of Practice (FAO)

E-Agriculture is a global Community of Practice, where people from all over the world exchange information, ideas, and resources related to the use of information and communication technologies (ICT) for sustainable agriculture and rural development.

E-Agriculture Community is made up of over 12,000 members from 170 countries and territories, members are information and communication specialists, researchers, farmers, students, policy makers, business people, development practitioners, and others.

Members have a common interest that brings them together, that of improving policies and processes around the use of ICTs in support of agriculture and rural development, in order to have a positive impact on rural livelihoods. [10]

FAO, the UN Agency assigned to lead the development and subsequent facilitation of ICT activities on agriculture, engaged various stakeholders at all levels creating this global Community of Practice, where people from all over the world exchange information, ideas, and resources related to the use of ICTs for sustainable agriculture and rural development

The objective of the e-Agriculture Community is to serve as a catalyst for institutions and individuals in agriculture and rural development to share knowledge, learn from others, and improve decision making about the vital role of ICTs to empower rural communities, improve rural livelihoods, and build sustainable agriculture and food security. [10]

1.4.2 ICT in Agriculture Sourcebook (World Bank)

The ICT in Agriculture e-Sourcebook, Updated Edition, is made possible by a number of key individuals, donors and partner organizations. The original ICT in Agriculture e-Sourcebook was published in 2011, and financed by the Ministry for Foreign Affairs of Finland under the Finland / infoDev / Nokia program on Creating Sustainable Businesses in the Knowledge Economy, whose generous contributions and ideas served as a foundation for its production. [11]

ICT-enabled services often use multiple technologies to provide information. This model is being used to provide rural farmers with localized (nonurban) forecasts so that they can prepare for weather-related events. In resource-constrained environments especially, providers use satellites or remote sensors (to gather temperature data), the Internet (to store large amounts of data), and mobile phones (to disseminate temperature information to remote farmers cheaply)—to prevent crop losses and mitigate the effects of natural adversities.

Other, more-specialized applications, such as software used for supply chain or financial management, are also becoming more relevant in smallholder farming. Simple accounting software has allowed cooperatives to manage production, aggregation, and sales with increased accuracy.

Hundreds of agriculture specific applications are now emerging and are showing great promise for smallholders, as illustrated in the more than 200 project-based case studies and examples in this Sourcebook. In order to exploit the possibilities, countries have two tasks:

- To empower poor farmers with information and communication assets and services that will increase their productivity and incomes as well as protect their food security and livelihoods.
- To harness ICT effectively to compete in complex, rapidly changing global markets (avoiding falling behind the technology curve). [11]

1.4.3 InfoDev (World Bank Group) and Tech Hubs

InfoDev, a global trust fund program on Information and Development supports entrepreneurs in high-growth sectors in more than 70 countries. Through innovative pilot programs on early-stage financing, business training and regional and global networks, InfoDev focuses on climate technologies, agribusiness, and digital innovation, facilitate the growth of competitive ventures, and the creation of jobs and services that benefit communities.

Based on the network of mLabs and mHubs, InfoDev facilitate the development of building mobile innovation communities which research the app economy of emerging and frontier markets, including in agriculture. For example, *Mfarm* enhances market access by providing information on prices in Kenya, *GreenHouse Pro* is an application geared to facilitate productivity growth in greenhouse farming, when *MkulimaBima* links farmers and insurance companies. [7]

1.5 Challenges of the agriculture industry :

1.5.1 An elevated increase in demographics

In the coming decades, world population is expected to grow to by 33 percent, to almost 10 billion by 2050, up from 7.6 billion (as of October 2017). By 2100, the global population is expected to reach 11.2 billion. That figure may understate actual fertility rates—under other scenarios, population could hit 16.5 billion.

Population growth will boost demand for food, even in a modest economic growth scenario, by roughly 50 percent as compared to 2013 agricultural output.[4]

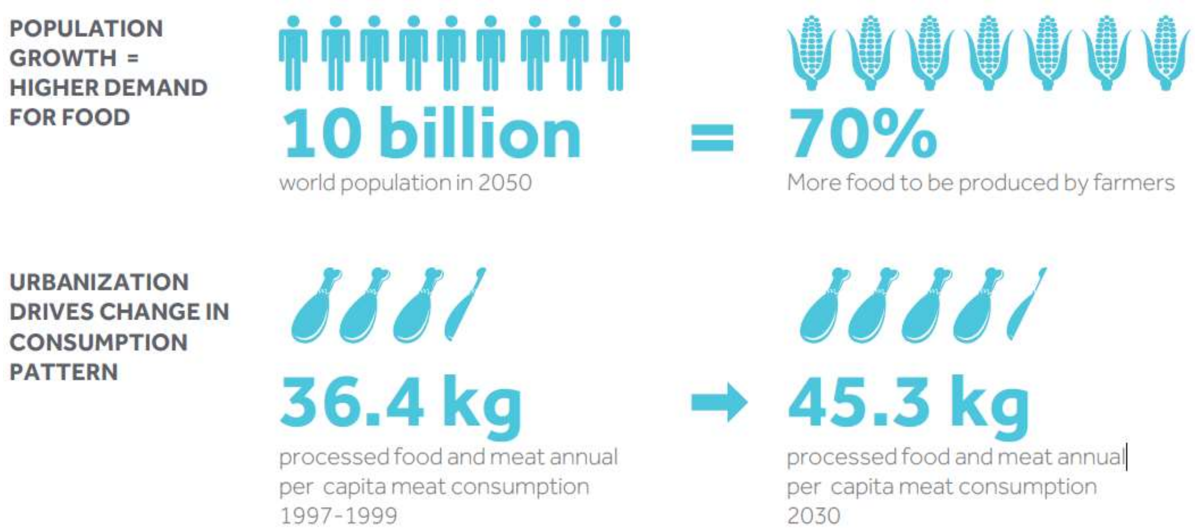


Figure 4 DEMOGRAPHICS INCREASMENT

1.5.2 Current uses of natural

The world's farmland is becoming increasingly unsuitable for production: On the basis of certain metrics, 25 percent of all farmland is already rated as highly degraded, while another 44 percent is moderately or slightly degraded. Water resources are highly stressed, with more than 40 percent of the world's rural population living in water-scarce areas.

Approximately 80 percent of global deforestation is driven by agricultural concerns. And while clearing vegetation to make way for farmland does not directly produce soil degradation, and is necessary for land clearage, it does so indirectly by eroding water resources. This last point is worthy of note: Although irrigation systems have maximized usage efficiency, growing populations make water security and scarcity a real concern. The investment deemed necessary until 2050 is $1 trillion for irrigation water management in developing countries alone.[4]

1.5.3 Climate change

Climate change is a fact and it is rapidly altering the environment. The degree of manmade emissions of greenhouse gases (GHGs) has reached the highest in history, according to a 2014 report of the Intergovernmental Panel on Climate Change (IPCC).

Climate change will affect every aspect of food production: Increasing variability of precipitation and more droughts and floods is likely to reduce yields. Climate change will contribute to existing long-term environmental problems, such as groundwater depletion and soil degradation, which will affect food and agriculture production systems.

Without efforts to adapt to climate change, food insecurity will increase substantially. Climate change's impact on global food security will relate not merely to food supply, but also food quality, food access, and utilization.[4]

1.5.4 Food waste

Between 33 percent to 50 percent of all foods produced globally is never eaten, and the value of this wasted food is more than $1 trillion. To put that in perspective, US food waste represents 1.3 percent of total GDP. Food waste is a massive market inefficiency, the kind of which does not persist in other industries.

Meanwhile 800 million people go to bed hungry every night. Each and every one of them could be fed on less than a quarter of the food that is wasted in the US, UK, and Europe each year.

Because we have a globalized food supply system, demand for food in the West can drive up the price of food grown for export in developing countries, as well as displace crops needed to feed native populations.[4]

1.6 Plant Disease

Plant pathologists have to rely on symptoms for the identification of a disease problem. Because similar symptoms can be produced in response to different causal agents, the use of symptoms alone is often an inadequate method for disease identification. The identification of the disease-causing agent may take a week or more. One needs to ask many questions related, in order to eliminate or identify possible causes of the problem. They also need to consider various environmental and cultural factors. As a result of his questions and observations they may:

- Be able to identify a disease and disease-causing agent,
- Be able to narrow the problem down to several possibilities which will require further study in the laboratory before he can make a final diagnosis, or
- Be completely baffled by the problem.[12]

We will take an example of the diseases and various that can affect tomato plant which is associated with accurate plant disease diagnosis.

1.6.1 Bacterial spot of tomato

Bacterial spot develops on seedlings and mature plants. On seedlings, infections may cause severe defoliation. On older plants, infections occur primarily on older leaves and appear as water-soaked areas. Leaf spots turn from yellow or light green to black or dark brown. Older spots are black, slightly raised, superficial and measure up to 0.3 inch (7.5 mm) in diameter. Larger leaf blotches may also occur, especially on the margins of leaves. Symptoms on immature fruit are at first slightly sunken and surrounded by a water-soaked halo, which soon disappears. Fruit spots enlarge, turn brown, and become scabby.[12]

1.6.2 Leaf mold

Yellow spots without a definite margin appear on the upper leaf surface and olive-green to brown or purplish masses of spores and velvety growth appear on the lower leaf surface. Disease symptoms appear first on the older leaves. As the disease progresses, the leaves become chlorotic, then necrotic, followed by drying and defoliation. Although this is primarily a foliar disease, unripe fruit may occasionally develop dark leathery lesions[12]

1.6.3 Tomato mosaic

Symptoms can be found during any growth stage and all plant parts are affected. Generally, infected plants have a light or dark green mottling or mosaic with distortion of younger leaves, and stunting to varying degrees. Severely affected leaves may have a "fernlike" appearance and may show raised dark green areas. Fruit set may be severely reduced in affected plants. There may be internal browning of the fruit wall, yellow blotches and necrotic spots may occur on green or ripe fruit. Some strains can cause yellow mottling of leaves, others cause dark necrotic streaks in stems, petioles, leaves or fruit, or other symptoms to occur.[12]

Those are some of the diseases that can effect tomato plant and most of them can be detected from it leaves and treatment of those diseases is different so you have to make sure what disease before starting the treatment.

The next table will represent sample picture of leafs with the named diseases:

Disease Name	Image
Bacterial spot of tomato	

Leaf mold	
Tomato mosaic	

Table 1 Tomatos Diseases

1.7 Conclusion

The use of information and communication technologies (ICTs) in the agricultural sector could help reduce poverty and improve food security. Smart farming will develop the workforce through the creation of jobs in surplus areas and address the shortage of agricultural labor.

In this chapter, we have seen the use of information and communication technologies in the agricultural sector and platforms and programs of ICT applications in agriculture, and we have also seen a number of challenges of the agriculture industry.

Chapter 02

Chapter 02

Generalities on the Internet of Things and Related Work

2.1 Introduction

The term "Internet of Things" has defined to explain the variety of technologies and analysis disciplines that enable the web to achieve out into the important world of physical objects. Extending the web will provides connection, communication, and internal networking between devices and physical objects, or Things, may be a growing trend that's typically mentioned as internet of Things. This sometimes referred as the internet of Objects. It represents of subsequent evolution the web, taking a large leap in its ability to analyze and distribute the data that we can change into information, knowledge and ultimately, wisdom.[13]

In this chapter, we will give some definitions on the Internet of Things and see it architectures and we will also list the elements of the Internet of Things, the application domains and some of the application protocols, service discovery protocols and infrastructure protocols used in it and finally the challenges of IoT. Then, we present some works and studies related to the surveillance of the Internet of Things and robotic in the field of agriculture. Finally, we will discuss a comparison between this works and extract the key point that should have an IoT in intelligent agriculture.

2.2 Definition of IoT

2.2.1 Definition 1

Internet of things (IoT) represents the connection between any devices with Internet including cell phone, home automation system and wearable devices . This new technology can be considered the phase changer of the healthcare applications concerning the patient's health using low cost.[14]

2.2.2 Definition 2

A "thing" is any object or device with embedded electronics that can transfer data over a network — without any human interaction. So imagine if you had smart devices in your car, your workplace or even on yourself.

The Internet of Things can make running your enterprise easier and reinvent the way you interact with the physical world.[15]

2.3 Fundamental Components of IoT

IoT is dependent technology. It is being established by different independent technology and devices which make fundamental components of IoT. Components are:

- Hardware tools making physical objects responsive and giving them capability to retrieve data and respond to instructions.
- Software technology enabling the data collection, storage, processing, manipulating and instructing.
- Communication interface most important of this entire communication infrastructure which is involving protocols and technologies helps to devices to talk and communicate with each other and transfer the data.
- Smart system for IoT is driven by the combination of :
  - Sensors + connectivity + people and processes.

The interactions between these things are creating new type of application which is smart enough for different functions. [14]

2.4 How Does IoT Work

The Internet of Things (IoT) allows the interconnection of different smart objects via the Internet. Thus, for its operation, several technological systems are necessary. These technologies are: RFID, WSN, SCADA and M2M, and they called The four pillars of IoT:

2.4.1 The Four Pillars and Their Relevance to the Network

2.4.2 The Four Pillars Definitions

2.4.2.1 Machine-to-Machine (M2M)

the IoT will strongly rely on a large number of M2M communications technologies, which can be classified with respect to various criteria such as standard format (public or private); network medium (wired or wireless); purpose (general or layer-specific); and age (emerging or legacy).

Between all the various M2M technologies, we can cite the short range wireless communications technologies (e.g. IEEE 802.15.4, IEEE 802.15.4a, NFC and Bluetooth) that meet the requirements imposed by M2M deployments targeting IoT scenarios and, in turn, the IoT protocols that aim to bring the current Internet's layer based approach to the IoT domain (6LoWPAN, CoAP and ZigBeeIP).

It is therefore important to highlight the current efforts towards the standardization of cross-vertical M2M service layers for the aforementioned technologies, which will lay the foundation for a truly horizontal IoT. To this purpose, in this subsection we contrast the aforementioned heterogeneous communication technologies, comparing them in terms of their technical features and elaborating on their role within the ongoing M2M service layer standardization.[16]

Some of the key features of M2M communication system are given below:

a) Low Mobility : M2M Devices do not move, move infrequently, or move only within a certain region
b) Time Controlled : Send or receive data only at certain pre-defined periods
c) Time Tolerant : Data transfer can be delayed
d) Packet Switched : Network operator to provide packet switched service with or without an MSISDN
e) Online small Data Transmissions: MTC Devices frequently send or receive small amounts of data.

f) Monitoring: Not intend to prevent theft or vandalism but provide functionality to detect the events
g) Low Power Consumption : To improve the ability of the system to efficiently service M2M applications
h) Location Specific Trigger : Intending to trigger M2M device in a particular area e.g. wake up the device

2.4.2.2 RFID

RFID [17] systems are composed of three main components: RFID tags, reader, application system, as shown in the next Figure:

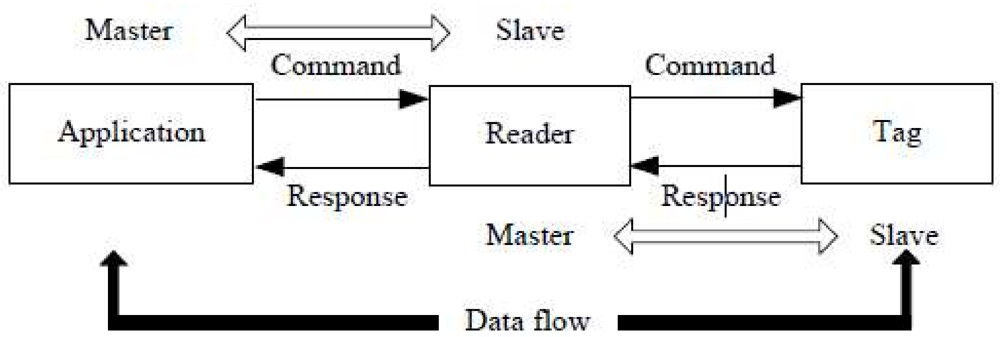


Figure 5 The components of a RFID system

RFID tags: also known as transponders (transmitter/ responder), are attached to the objects to count or identify. Tags could be either active or passive. Active tags are those that have partly or fully battery powered, have the capability to communicate with other tags, and can initiate a dialogue of their own with the tag reader. Passive tags, on the other hand, do not need any internal power source but are powered up by the tag reader. Tags consist mainly of a coiled antenna and a microchip, with the main purpose of storing data. [17]

Reader: also known as transceiver (transmitter/receiver) made up of a radio frequency interface (RFI) module and control unit. Its main functions are to activate the tags, structure the communication sequence with the tag, and transfer data between the application software and tags. [17]

Application system: also called data processing system, which can be an application or database, depending on the application. The application software initiates all readers and tags activities. RFID provides a quick, flexible, and reliable way for electronically detecting, tracking and controlling a variety of items. RFID systems use radio transmissions to send energy to a RFID tag while the tag emits a unique identification code back to a data collection reader linked to an information management system. The data collected from the tag can then be sent either directly to a host computer, or stored in a portable reader and up-loaded later to the host computer. [17]

2.4.2.3 WIRELESS SENSOR NETWORK (WSN)

The wide wireless sensor network application field can be divided into three main categories according to : Monitoring space, monitoring objects and monitoring interactions between objects and space. The proposed classification can be extended by an additional category monitoring human beings.[18]

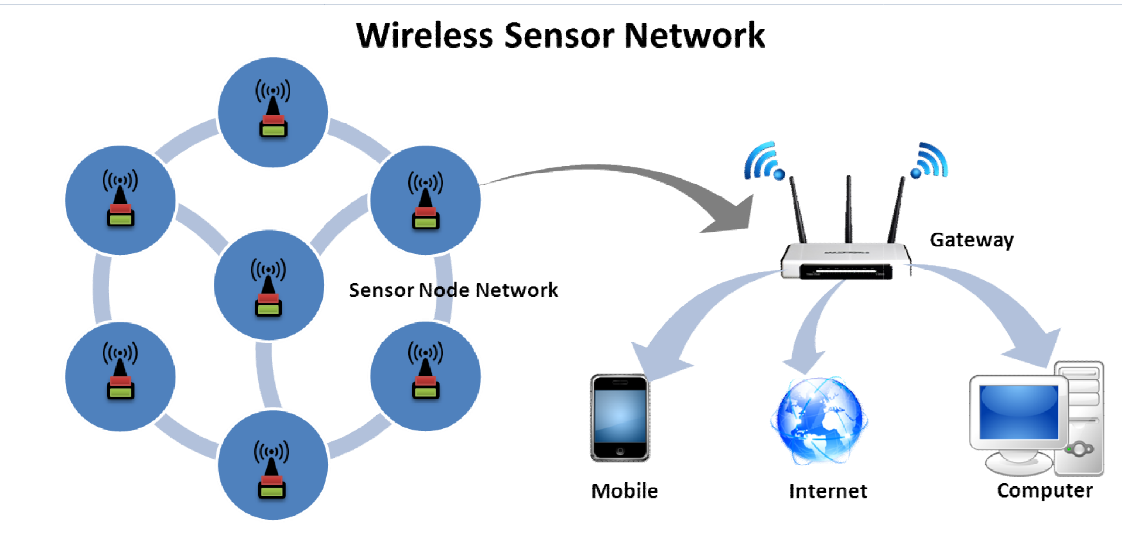


Figure 6 WIRELESS SENSOR NETWORK (WSN)

2.4.2.4 SCADA (SUPERVISORY CONTROL AND DATA ACQUISITION)

It is impossible to keep control and supervision on all industrial activities manually. Some automated tool is required which can control, supervise, collect data, analyses data and generate reports. A unique solution is introduced to meet all this demand is SCADA system.

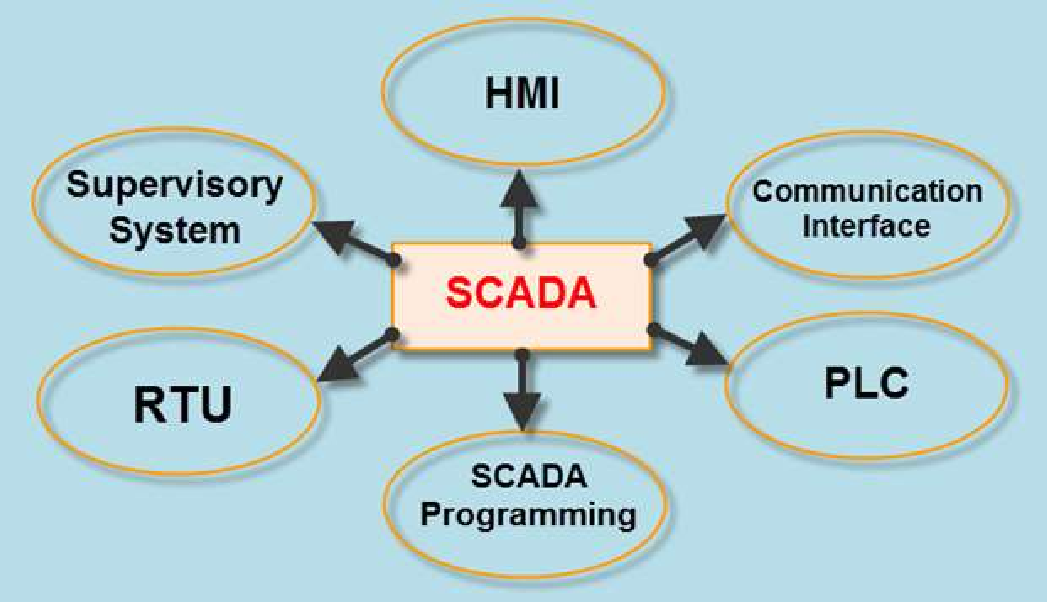


Figure 7 SUPERVISORY CONTROL AND DATA ACQUISITION

1. Human Machine Interface (HMI): It is an interface which presents process data to a human operator, and through this, the human operator monitors and controls the process.
2. Supervisory (computer) system: It gathers data on the process and sending commands (or control) to the process.
3. Remote Terminal Units (RTUs): It connect to sensors in the process, converting sensor signals to digital data and sending digital data to the supervisory system.
4. Programmable Logic Controller (PLCs): It is used as field devices because they are more economical, versatile, flexible, and configurable than special-purpose RTUs.
5. Communication infrastructure: It provides connectivity to the supervisory system to the Remote Terminal Units.

The next table presents a comparative between the four pillars

	Short-Range Whireless	Long-Range Whireless	Short-Range Whired	Long-Range Whired
RFID	Yes	Some	No	Some
WSN	Yes	Some	No	Some
M2M	Some	Yes	No	Some
SCADA	Some	Some	Yes	Yes

Table 2 Comparative between the four pillars

2.5 Architectures of IoT

There is no single consensus on architecture for IoT, which is agreed universally. Different architectures have been proposed by different researchers.

The Three and Five-Layer Architectures. The most basic architecture is three-layer architecture as shown in Figure 8. It was introduced in the early stages of research in this area. It has three layers, namely, the perception, network, and application layers.[19]

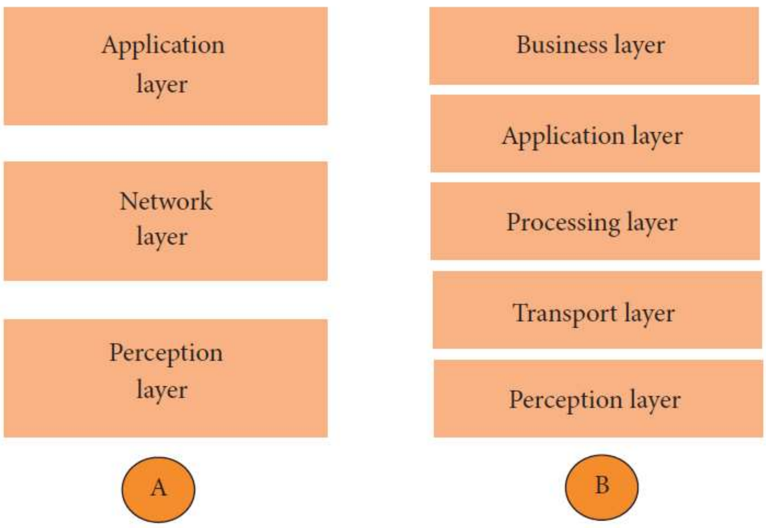


Figure 8 Architecture of IoT (A: three layers) (B: five layers).

- The perception layer is the physical layer, which has sensors for sensing and gathering information about the environment. It senses some physical parameters or identifies other smart objects in the environment. [19]
- The network layer is responsible for connecting to other smart things, network devices, and servers. Its features are also used for transmitting and processing sensor data. [19]
- The application layer is responsible for delivering application specific services to the user. It defines various applications in which the Internet of Things can be deployed, for example, smart homes, smart cities, and smart health. [19]

The three-layer architecture defines the main idea of the Internet of Things, but it is not sufficient for research on IoT because research often focuses on finer aspects of the Internet of Things. That is why, we have many more layered architectures proposed in the literature. One is the five layer architecture, which additionally includes the processing and business layers. The five layers are perception, transport, processing, application, and business layers. The role of the perception and application layers is the same as the architecture with three layers. We outline the function of the remaining three layers.

I. The transport layer transfers the sensor data from the perception layer to the processing layer and vice versa through networks such as wireless, 3G, LAN, Bluetooth, RFID, and NFC.

II. The processing layer is also known as the middleware layer. It stores, analyzes, and processes huge amounts of data that comes from the transport layer. It can manage and provide a diverse set of services to the lower layers. It employs many technologies such as databases, cloud computing, and big data processing modules.

I. The business layer manages the whole IoT system, including applications, business and profit models, and users' privacy. The business layer is out of the scope of this paper. Hence, we do not discuss it further. [19]

2.6 Protocols of IoT

Rather than trying to fit all of the IoT Protocols on top of existing architecture models like OSI Model, they have broken the protocols into the following layers to provide some level of organization:

- **Infrastructure** (ex: 6LowPAN, IPv4/IPv6, RPL)
- **Identification** (ex: EPC, uCode, IPv6, URIs)
- **Comms / Transport** (ex: Wifi, Bluetooth, LPWAN)
- **Discovery** (ex: Physical Web, mDNS, DNS-SD)
- **Data Protocols** (ex: MQTT, CoAP, AMQP, Websocket, Node)
- **Device Management** (ex: TR-069, OMA-DM)
- **Semantic** (ex: JSON-LD, Web Thing Model)
- **Multi-layer Frameworks** (ex: Alljoyn, IoTivity, Weave, Homekit)

2.7 Applications of IoT

The applications for Internet connected devices are extensive and multiple, ranging from household appliances to heavy industrial machinery. The ability to network embedded devices with limited CPU, memory and power resources means that IoT finds applications in nearly every field. Such systems could be in charge of collecting information. There is no end to the usage of IoT in technology, business and personal lives.[20]

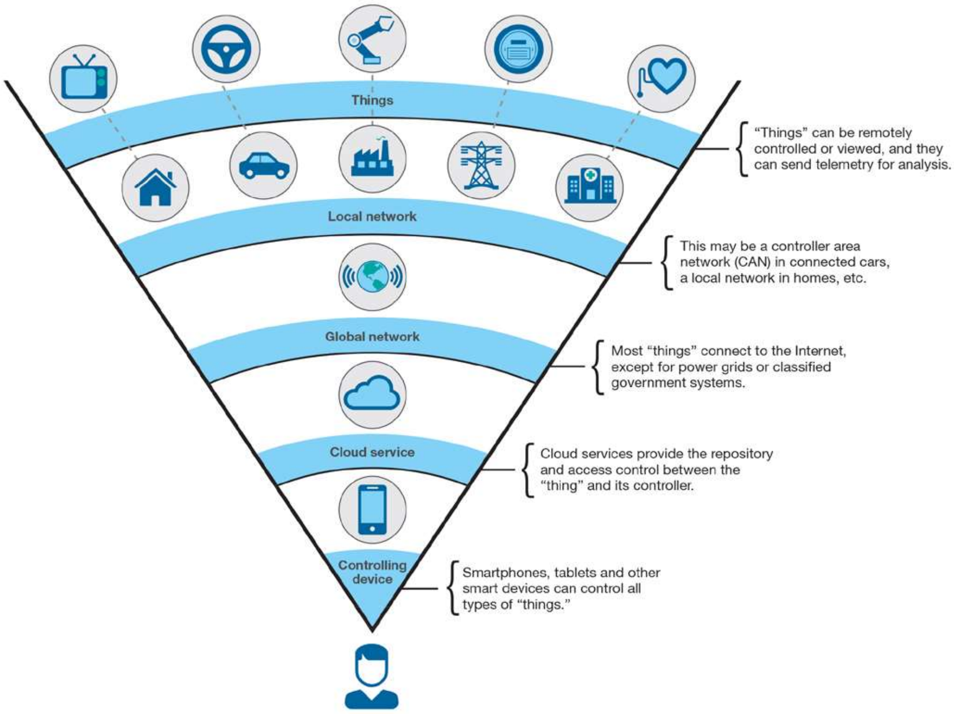


Figure 9 Human view of Internet of Things

2.7.1 Smart Home (Home Automation)

Smart home technology applied can provide users with more freedom and a higher quality of life. Household devices connected to Internet can be monitored and controlled at Home or even from any part of the world. A home automation system will control lighting, climate, entertainment systems, and appliances. It may also include home security such as access control and alarm systems. When connected with the Internet, home devices are an important constituent of the Internet of Things. [20]

2.7.2 Industrial Automation

Automation in industry is very critical, as there are harsh and unpleasant conditions for human beings. Instead of following manual processes, when taking a step further with automated control – by connecting the systems and controlling over the Internet, it gives great control for the employer/manager and monitoring since you can monitor not only from the company's premise but from anywhere. This facilitates productivity and ensures tasks/people can be monitored simultaneously. [20]

2.7.3 Security System

Burglar alarm, break detectors fitted in house or shops can be connected to Internet. This will give a high priority alert to owners and nearby police stations.[21]

2.7.4 Agricultural Automation

The Internet of things (IOT) is remodeling the agriculture enabling the farmers with the wide range of techniques such as precision and sustainable agriculture to face challenges in the field. IOT technology helps in collecting information about conditions like weather, moisture, temperature and fertility of soil, Crop online monitoring enables detection of weed, level of water, pest detection, and animal intrusion in to the field, crop growth, and agriculture. IOT leverages farmers to get connected to his farm from anywhere and anytime. Wireless sensor networks are used for monitoring the farm conditions and micro controllers are used to control and automate the farm processes. To view remotely the conditions in the form of image and video, wireless cameras have been used. A smart phone empowers farmer to keep updated with the ongoing conditions of his agricultural land using IOT at any time and any part of the world. IOT technology can reduce the cost and enhance the productivity.[22]

2.8 IoT Challenges

Developing a successful IoT application is still not an easy task due to multiple challenges. These challenges include: mobility, reliability, scalability, management, availability, Interoperability, and security and privacy. In the following, we briefly describe each of these challenges.

2.8.1 Mobility

IoT devices need to move freely and change their IP address and networks based on their location. Thus, the routing protocol, such as RPL has to reconstruct the DODAG each time a node goes off the network or joins the network which adds a lot of overhead. In addition, mobility might result in a change of service provider which can add another layer of complexity due to service interruption and changing gateway.[23]

2.8.2 Reliability

System should be perfectly working and delivering all of its specifications correctly. It is a very critical requirement in applications that requires emergency responses. In IoT applications, the system should be highly reliable and fast in collecting data, communicating them and making decisions and eventually wrong decisions can lead to disastrous scenarios.[23]

2.8.3 Scalability

Scalability is another challenge of IoT applications where millions and trillions of devices could be connected on the same network. Managing their distribution is not an easy task. In addition, IoT applications should be tolerant of new services and devices constantly joining the network and, therefore, must be designed to enable extensible services and operations.[23]

2.8.4 Management

Managing all These devices and keeping track of the failures, configurations, and performance of such large number of devices is definitely a challenge in IoT. Providers should manage Fault, Configuration, Accounting, Performance and Security (FCAPS) of their interconnected devices and account for each aspect.[23]

2.8.5 Availability

Availability of IoT includes software and hardware levels being provided at anytime and anywhere for service subscribers. Software availability means that the service is provided to anyone who is authorized to have it. Hardware availability means that the existing devices are easy to access and are compatible with IoT functionality and protocols. In addition, these protocols should be compact to be able to be embedded within the IoT constrained devices.[23]

2.8.6 Interoperability

Interoperability means that heterogeneous devices and protocols need to be able to inter-work with each other. This is challenging due to the large number of different platforms used in IoT systems. Interoperability should be handled by both the application developers and the device manufacturers in order to deliver the services regardless of the platform or hardware specification used by the customer.[23]

2.9 Related Work

The following works implement IoT in different areas such as agriculture and energy management or try to improve some features like cost, power consumption, etc.

2.9.1 Ecorobotix

The robot works without being controlled by a human operator. It covers the ground just by getting its bearings and positioning itself with the help of its camera and GPS. Its system of vision enables it to follow crop rows, and to detect the presence and position of weeds in and between the rows. Two robotic arms then apply a micro dose of herbicide, systematically targeting the weeds that have been detected. In bare fields or meadows the robot positions itself precisely thanks to its GPS RTK. [24]

Reliance on solar power makes the robot completely autonomous in terms of energy.

How it works

- Systematic sweep of the entire field – no corners are left out.
- The robot arm places a micro dose just at the right spot, without any wastage.
- Weeds are detected with a success rate in excess of 95% both in and between rows.
- The robot can easily be transported by tractor.

Figure 10 Ecorobotix

2.9.2 Naïo Technologies

Naïo Technologies have a host of robots that not only act as the perfect farm hand using techniques that preserve and protect the local environment. [25,26]

The robots have the ability to weed, and assist during harvesting. As stated by the team, "We want to provide all participants in the agriculture process with access to the latest technology, to help grow healthier, more abundant and environmentally friendly crops."

2.9.2.1 Areas of expertise

- Navigation (Hybrid system)
- Vision
- Connected sensors
- Monitoring / Decision Support Tools
- Agronomy
- CAD
- Electronics
- Automatism
- Laser Guidance Technology
- Vision Guidance Technology

Figure 11 Naïo Technologies

2.9.3 Agribotix

Using drones for agriculture is a hot topic these days, and for good reason. These unmanned aerial vehicles (UAVs), are rapidly becoming a core tool in farmer's precision equipment mix. [27]

Drones will play a huge role in monitoring large areas of crops. Agribotix is a low-cost tool for farmers, to collect crop data over time, or in real-time.

From taking precise aerial photos to recording video, the company's collection of drones even has infrared sensors that can measure the health of crops while in the air.

Figure 12 Agribotix

2.9.4 An IoT approach for implementing smart greenhouses connected

From massive agribusiness players to small organic farmers, growers all over the world today are using the Internet of Things to reduce their consumption of water and energy, and improve the quality or yield of their products. In this work, they are interested on agriculture area problems, precisely on greenhouses management and the reduction of energy consumption where they have proposed a new smart multitenant solution based on IoT and Cloud Computing technologies in order to give farmers the ability to monitor, supervise and control an important number of normal and sensitive greenhouses without the need to physically intervene each time to make regular actions. [28]

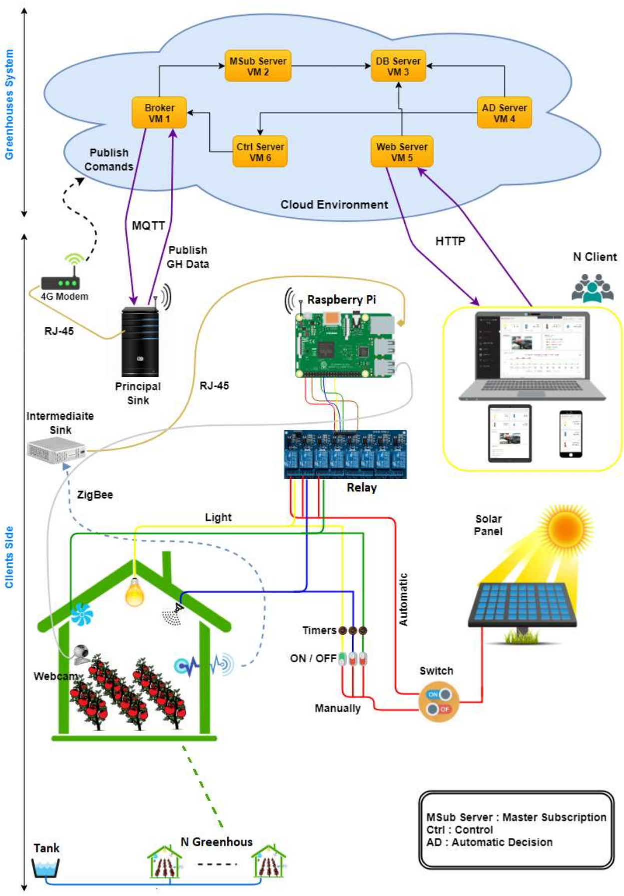


Figure 13 An IoT approach for implementing smart greenhouses connected

2.10 Comparison of related work

After our study of related work presented, we noticed that to have an IoT solution, we should first ensure these points:

- The choice of specific sensors and actuators.
- Optimize redundancies and errors in the data collected through the wireless sensor network, and optimize and minimize the energy cost.
- Selecting the appropriate protocol for our architecture.
- Selecting the methods and the technology that we will use.

In the next table we did a comparison between the previous related work versus metrics such as sensor types, Internet access . . . etc.

Topic	Sensor type	Internet access	Technology / Method	Cloud Solution
Ecorobotix	• Color megapixel camera • GPS RTK • compass	Short (Wi-Fi) or long distance (mobile phone networks)	• Systematic sweep of the entire field • Imaging System IoT	IaaS
Naïo Technologies	• Light • Humidity • Temperature	• Wi-Fi • LTE	• Navigation • Laser Guidance Technology • Vision Guidance Technology	IaaS
Agribotix	Sensor -1” CMOS Effective pixels: 20 M	• Wi-Fi • LTE	• AG intelligence • Imaging System	IaaS/PaaS
Surveillance	• Ground • Humidity • Temperature • Solar radiation • CO2	• Wi-Fi	• IoT • ToF (Time of Flight)	PaaS
An IoT approach for implementing smart greenhouses connected	Light Humidity Temperature	• Wi-Fi • LTE	• IoT • Genetic algorithms	IaaS/PaaS

Table 3 Comparison between Related works

2.11 Conclusion

Throughout this chapter, we have deliberately chosen simple and varied definitions for each tool and concept on the Internet of Things, in order to remove ambiguity and to demystify certain confusions. We also presented how IoT works and IoT architectures, and noted that there are two types of architecture most used. We talked about the different elements of the IoT, and we classified the protocols of this technology into three classes, in addition we presented the different areas of application of the IoT, and finally we talked about the challenges of IoT. and we have also seen a number of related works, from these works we have been able to select some key points such as the types of sensors, and the technology or method used, these points are essential to give a good IoT solution.

Chapter 03

Chapter 03

System conception

3.1 Introduction

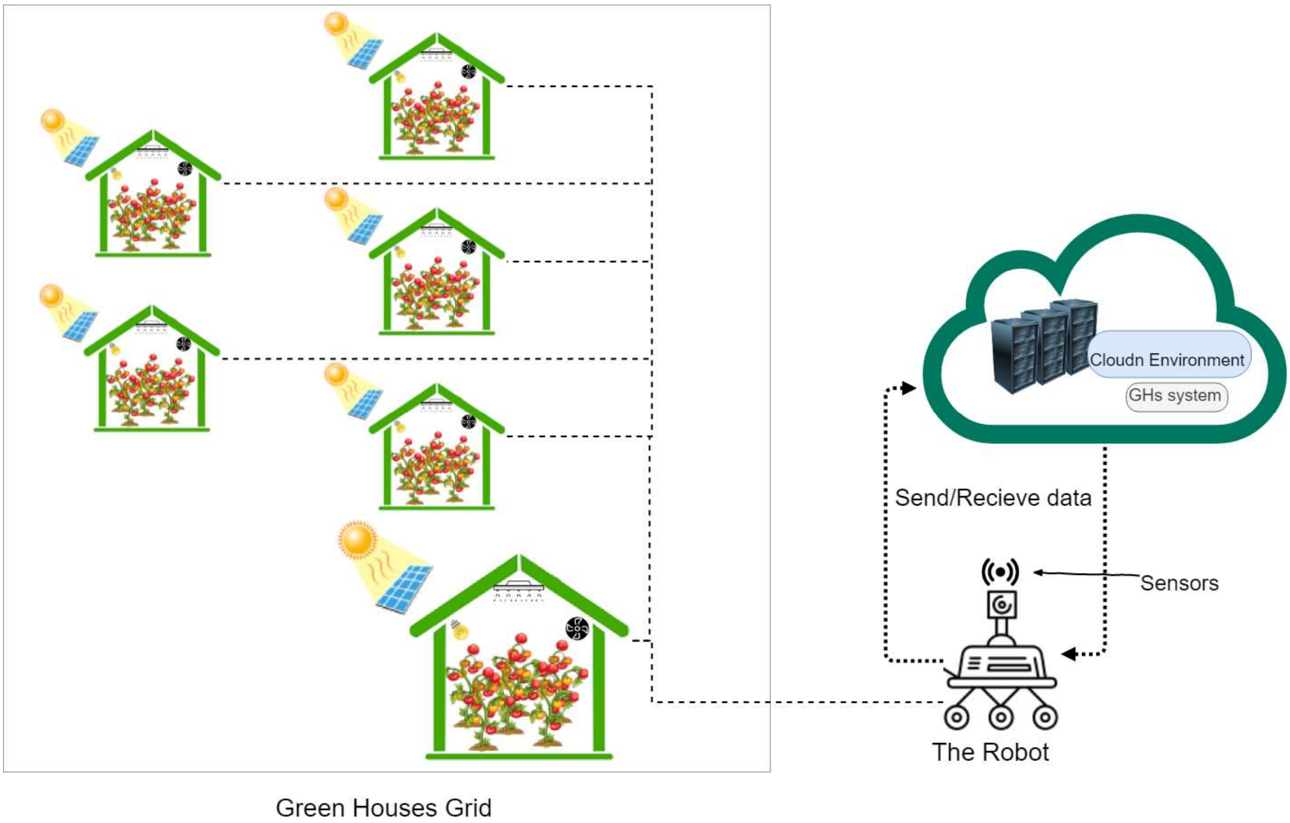
In the life cycle of a project, analysis and design are two primary and important phases in the realization of the application. In this chapter, we will present the specification and needs analysis as well as the system design. We chose the UML standard language (Unified Modeling Language) to model our system. It offers standard notations that simplify the reality to understand the system to develop. Then, we will clarify a global view of our project, describing the general architecture that we will follow in the realization part. Then we will build a genetic algorithm that optimizes the consumption of energy resources and makes an intelligent decision as long as the natural evolution of the plant is maintained.

3.2 General Architecture

In order to clarify our work, we have made two architectures a simplified general architecture and a detailed architecture which explains in detail all the components, the figure below represents the general architecture, we see that we have greenhouses each greenhouse will be equipped with an Arduino and relays, as well as a number of actuators such as fan and irrigation system . . . etc. Then we have our robot connected with several sensors which collect information such as temperature and humidity these sensors are connected to a Raspberry Pi micro-controller. The robot also contain a camera connected to the Raspberry Pi; the micro-controller is responsible for two functions:

- Collect data with sensors and camera and send it to the GHs system via a 4G modem.
- Receive commands from GHs System, in this case the microcontroller acts by sending commands to the Arduino in the GH that's responsible of controlling the actuator installed in the greenhouse.

The Cloud Environment (CE) hosts the different components of the GHs system, the CE is provided by a third party.



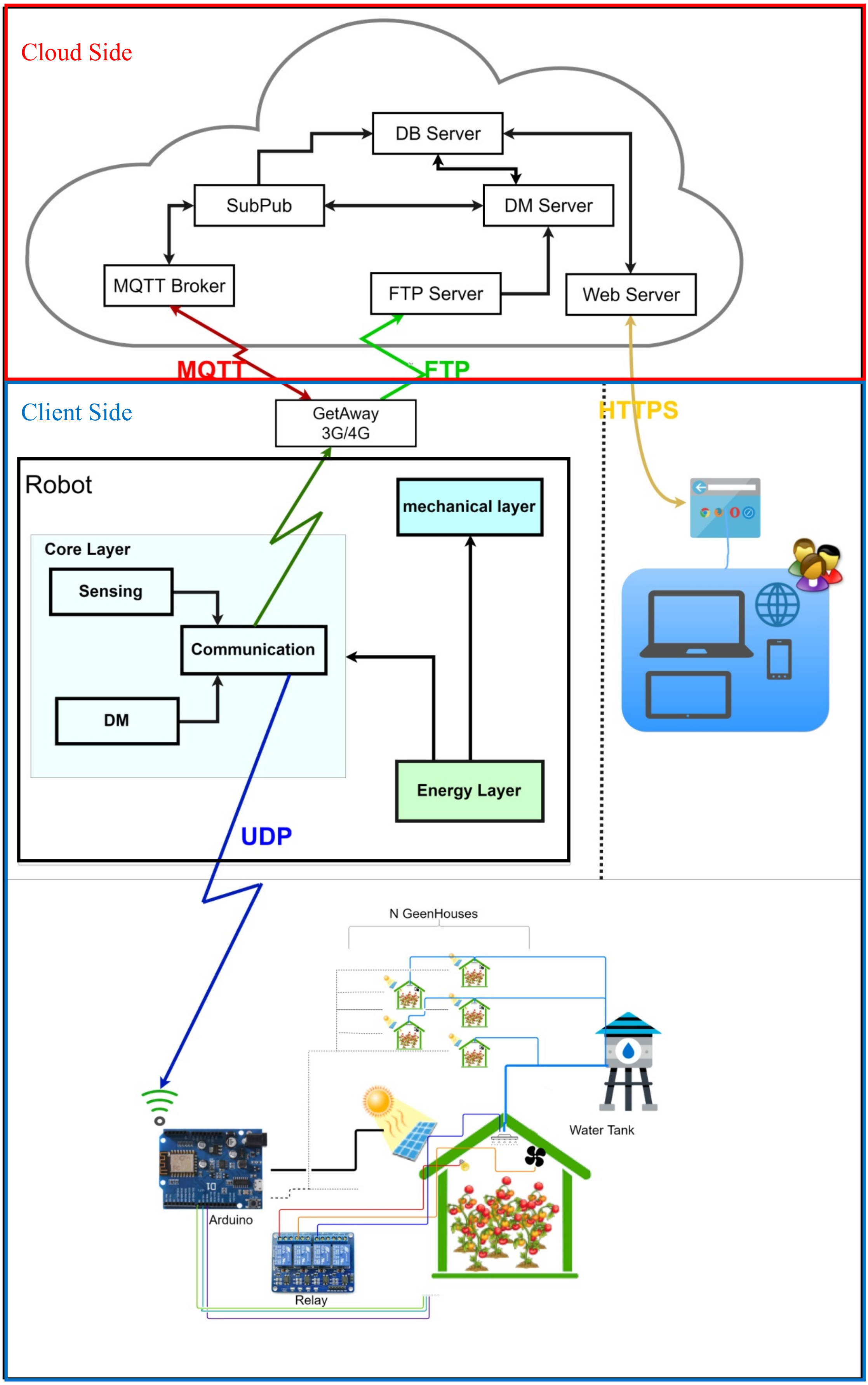
3.3 Detailed architecture

In our architecture there are 2 sides which are:

Client side: This side represents the monitored greenhouses (which are located either in an agricultural field or in a greenhouse field) + equipment used to connect them to the GHs system.

Provider side: represents the components that are located in the cloud and are responsible for recovering data received from the client side to show statistics and control resources of greenhouses, we will explain later the functionality and components of this system.

The Cloud Environment (CE): This is the cloud computing infrastructure in which the GHs system is hosted. This environment can be either using Openstack or Vmware cloud technologies or by obtaining a third-party cloud provider.


Cloud Side
DB Server
SubPub
DM Server
MQTT Broker
FTP Server
Web Server
MQTT
FTP
Client Side
GetAway
3G/4G
HTTPS
Robot
mechanical layer
Core Layer
Sensing
Communication
DM
Energy Layer
UDP
N GeenHouses
Water Tank
Arduino
Relay

3.3.1 Main components on the client side

To connect a greenhouse, we need a set of electronic components that are micro controller (Arduino) with relay and the robot.

3.3.1.1 Deployment and functionality in the greenhouse

- We put our actuators in the greenhouse (light, fan, window, pump ... etc.) in the appropriate place, these actuators are ordered by the microcontroller.
- The arduino have two roles, the first is the recovery the commands from the raspberry using UDP , the second role is to control the actuators with the pins and the relay module.
- The arduino will be connected directly to the access point of the raspberry and a direct communication with the micro controller
- Source of energy: the use of a solar panel would be a good choice in a region rich in solar energy.

3.3.1.2 The Robot

3.3.1.2.1 The components of the robot

The architecture of the robot Consisting of three main layers :

A. Energy layer

responsible of supplying the robot with the energy needed to function completely, the power supply that we will use is assemblage of set of batteries 4.2v 1830MA , since we need a 8V or higher and at least 2A , we will connect 4 batteries joined in series and parallel so we will have double voltage and double amperage rating like the next figure, This energy source will be used both to run the micro controller and all other components.

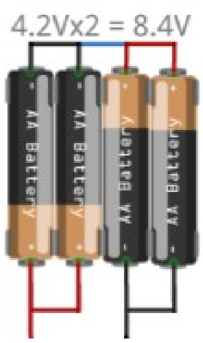


Figure 14 batteries joined in series and parallel

B. Mechanical layer

The robot have to navigate through the greenhouses in the open field and this layer is the responsible to do so, the robot navigate in the field using 6 dc motors with 6 wheels and connect them with the following architecture :

Figure 15 Right Side of the robot base

The DC motors will be connected on the ends of each leg. The front of the base will be movable so it can adjust and rotate when its needed, the left side will be just same as the right side but on the top will have only one hole so it will be able to rotate.

To control the motors we will be using motor drivers each one can connect to two motors because it have only two out puts , so we will connect the two front motors to one output and the other motor will be connected to the other motor, and the motor driver will be connected to GPIO of the raspberry , we also have a PMW in put in the motor driver and this will be used to control the speed of the motors, the speed will be between 0 and 100% and it will be sent from the raspberry as an integer.

The next figure will demonstrate how it will work:

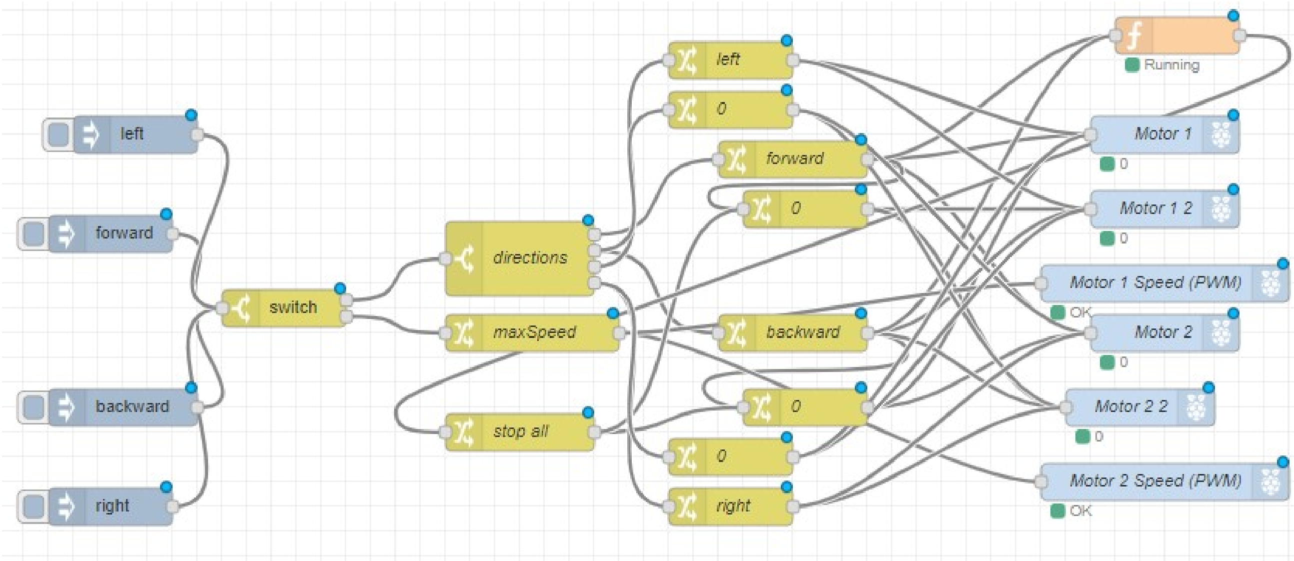


Figure 16 Mechanical layer navigatin

Using node-red on the micro controller, to control the motor all we need is to send the switch node a string with (forward, backward, left or right), the switch will send that same message to two different nodes, the maxSpeed node control the speed of the motors, the direction node will split the message received to 4 different nodes, each node have it own output to the gpio:

- **Forward:** all motors gpio will be (1).
- **Backward:** all motors gpio will be (0).
- **Left:** Left sides motors will be (1) go forward and the right sides will be (0) to go backward.
- **Right**: Right sides motors will be (1) go forward and the left sides will be (0) to go backward.

We also have a servo motor on the top and it will be used to control the head of the robot so it can turn 180°

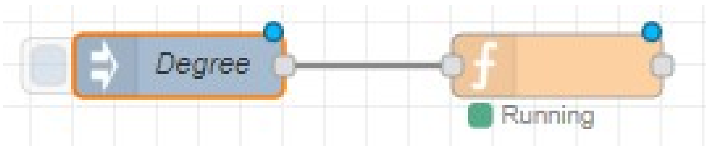


Figure 17 Mechanical layer Head turning

The degree node is used to send a float between 2.5 (max left) to 10 (max right),that message will be received from the function and it will execute to turn the head as the given degree.

C. Core layer

It contains three parts sensing, DM (decision making) and communication and each part have it own role in the system:

a. **Sensing**

We are using four sensors along with the pi camera, so robot can collect data from the green houses , the sensors are humidity, temperature ,light sensor and ultrasonic.

The pi camera will be used for two main functions:

- The first function is to take picture of the plants to be send to the cloud environment
- The seconds functions is to detect the placement of the plants inside the greenhouse and also to detect the center of the door of the green house and this will be with streaming video from it directly to the DM.

b. **DM**:

Decision making in the micro controller will be responsible for process simple operations and that’s because of the micro controller not powerful enough to do big operations , in our case we will be using the DM after data been collected from sensors for :

- Analyzing the data collected from the ultrasonic sensor to detect if the robot is close to an object, and we have three type of object:
    - Obstacle and the robot have to stop to avoid the crushing
    - The greenhouse door and this case robot will send a message to the GH to open the door
    - A plant and in this case will take a picture to be send to the cloud environment
- Analyzing the data from the pi camera to find a plant or centralize to the green house’s door
- Process the messages received by the micro controller

c. **Communication**:

This is the most important part in the core layer, receiving and sending data , the role of the communication in the core layer is :

- Sending and receiving messages to and from the cloud environments via MQTT
- Sending and receiving messages to and from the greenhouses via UDP

3.3.2 The cloud environments (CE)

It's a multi-server environment, each server in the cloud environment have a special role :

MQTT Broker: MQTT Broker is responsible for distributing publisher messages to subscribers with the same subject in our architecture as the Broker distributes two types of messages (data messages and control messages). The data messages come from the micro controller in the robot and at the end of the broker to the main SubPub server. The control messages come from the DM server and using the end of the broker at the same micro controller that sends them to the arduino in the greenhouse.

SubPub Server: is an MQTT subscriber customer that subscribes to all data messages published by the primary Sink and distributed by the Broker, each time the SubPub Server has received data it stores them at the database server.

Decision making (DM) Server: This component is responsible for making an automatic decision regularly without the need for user intervention. Its role is to minimize the need for repetitive action by the user and can be configured to satisfy the best conditions for the crops by keeping the best degree of temperature or giving the right amount of water. This server is also responsible for detecting the diseases in the plants using a deep learning application.

Web server: This is the server responsible for granting access to the user to view the monitoring information on its greenhouses and statistics in the form of a web dashboard, the user can also control by this interface (Dashboard) by configuring a periodic automatic action (automatic decision server configuration).

FTP server: the FTP server needs a TCP/IP network for functioning and is dependent on usage of dedicated servers with one or more FTP clients. The FTP server is responsible for allowing the robot to upload photos of the plants to be treated by the DM.

Database (DB) server: back-end system of a database application, it performs tasks such as storage, data manipulation, and archiving.

3.4 Electronic diagram

In the first part we will demonstrate the electronic circuit diagram of our robot which contains a microcontroller, 6 DC motors, 2 motor drivers, our sensors (humidity and temperature sensor , light sensor), a relay , micro pump , a servo motor and the pi camera as showed in the next figure:

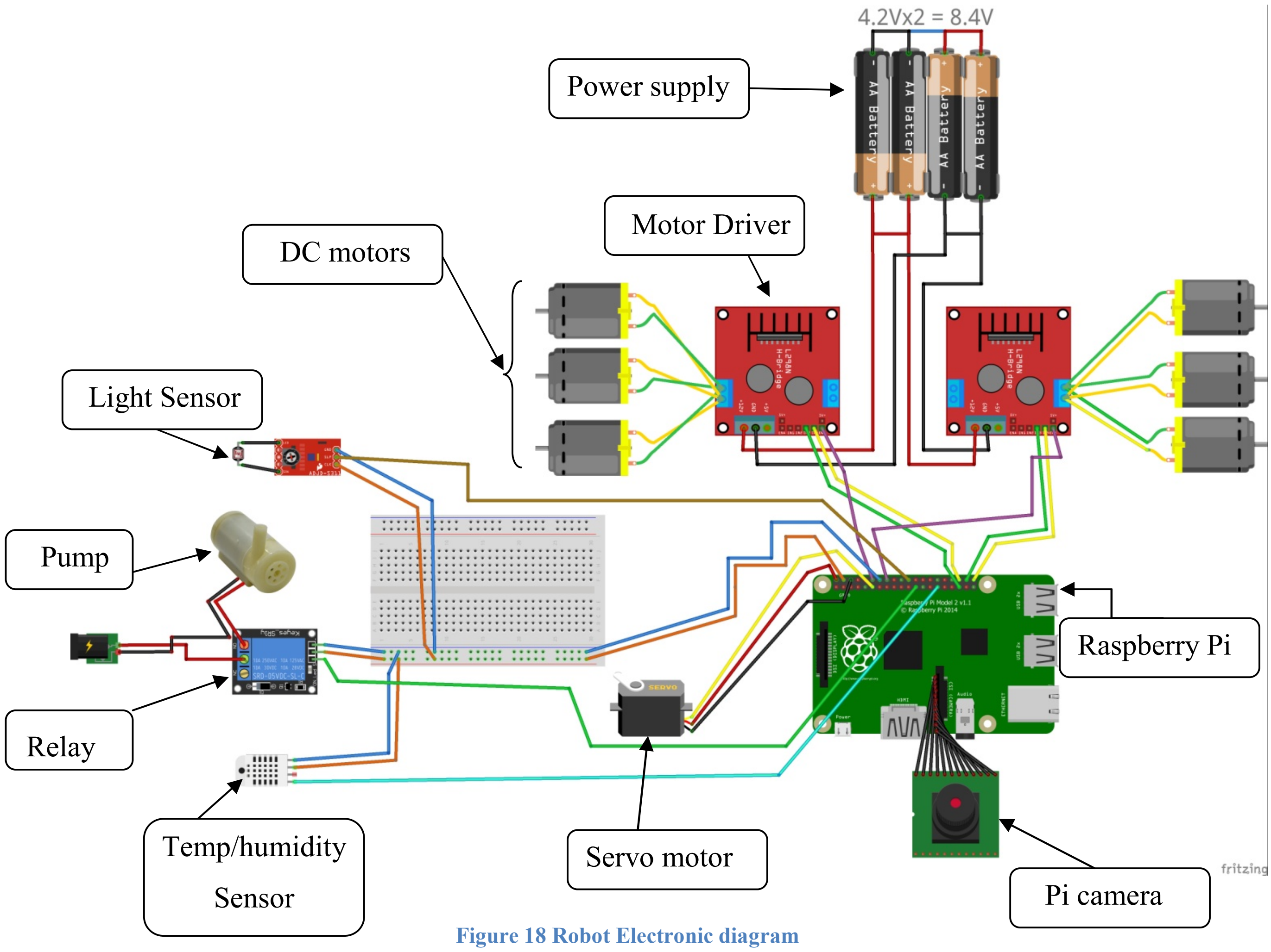


Figure 18 Robot Electronic diagram

In the second part is the electronic circuit diagram of the green house which contains an arduino, a 4 channel relay, a motor drivers, a dc motor, switches to switch between 12v and 220v as needed and the actuators (the lamp, the fan and the pump), as showed in the next figure:

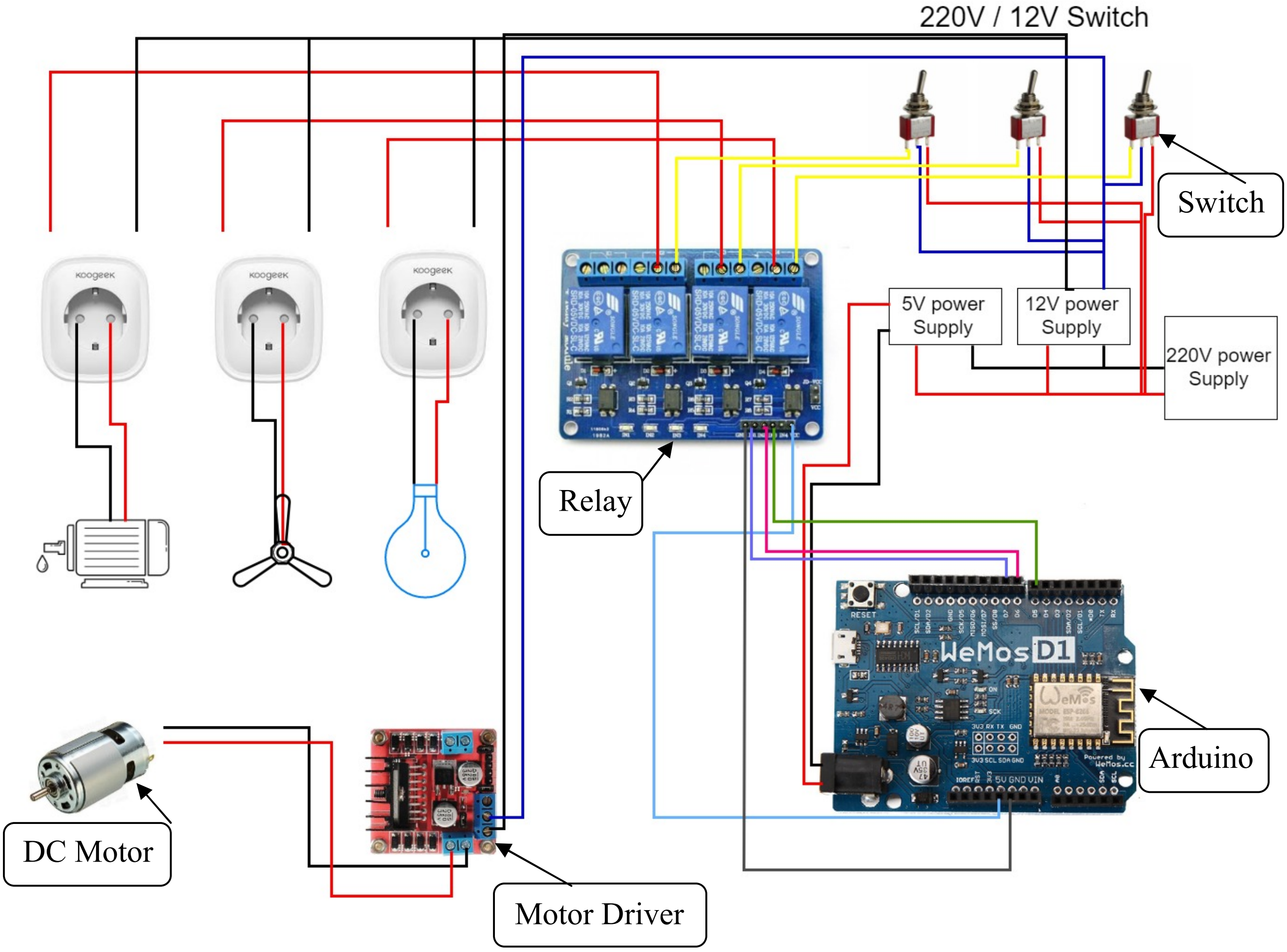


Figure 19 Greenhouse Electronic diagram

3.4.1 System analysis

In this section, we will explain the operation of the IoT monitoring system for the implementation of smart greenhouses and the robot, to better understand its operation, we illustrated the relationship and operation of the various components of the system in the diagrams, and we proposed a conceptual model for our main database system.

3.4.2 The purpose of the system

The Internet of Things and Cloud Computing and robotic represent the major IT trends of the moment. The objective of this work is to study these technologies in order to propose and implement a new solution for the implementation of a robot to manage the smart greenhouses (this includes: Greenhouse supervision, automatic and decision making, detecting diseases and spray the chemical product).

3.4.3 How our system works

This phase consists of understanding the context of the system. It's about determining the different features and the most relevant actors. The actor is a person, hardware or software as a service (SaaS), which is a model of software distribution across the cloud where the applications are hosted by the service provider. So we identified for our application the set of business needs that represent the actions that the system must perform:

Now we will take it step by step and each step with its own diagram to explain our system:

Step 1 : When the users come to our website firstly they will consult the home page

- The homepage: it is the main page of our application; it is distinguished from other pages by the fact that it is supposed to represent to the visitor the site on which it is clear and strong.

Step 2 : The user must have an account in our system, so for the new users they have to sign up, for signing up all what the user needs is the full name and an email and a password. As demonstrated in the next diagram :

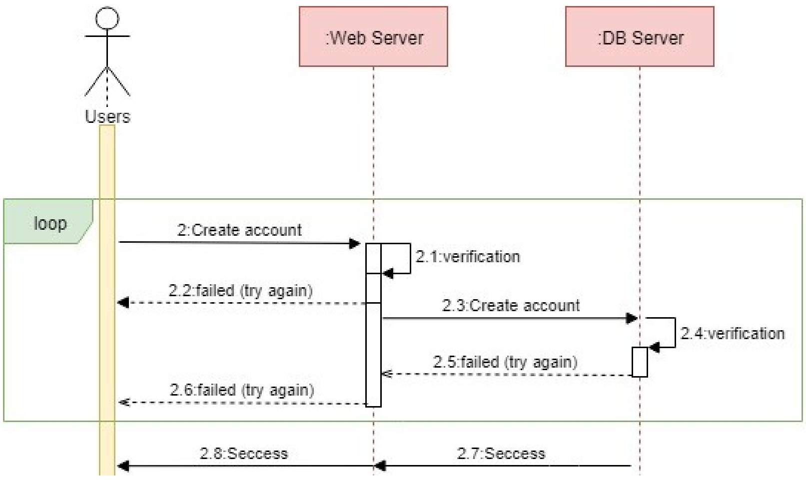


Figure 20 Sequence diagram of the "signing up" scenario

Step 3 : After signing up the users must login to their account so they can use the functions of our work, the next diagram will explain that:

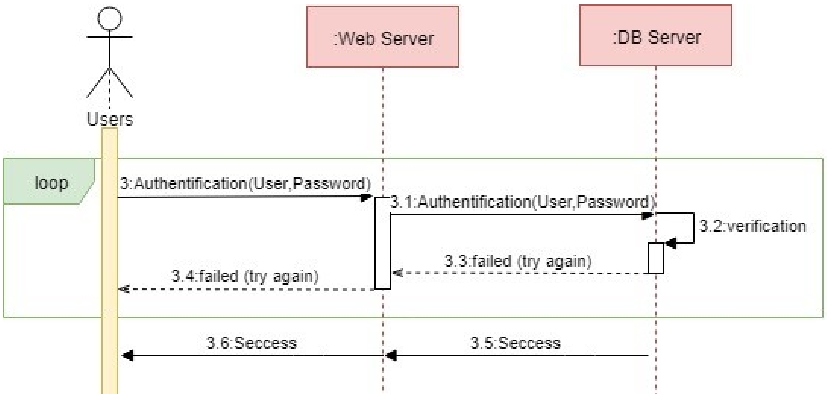


Figure 21 Sequence diagram of the "Login" scenario

Step 4 : The next step after login in for the first time is to link the robot to the user account, and to do so all what the user need is the serial number of the robot, each robot can be linked to one and only one user.

Step 5 : In this step the user have to add the greenhouses to the account , the user can add update delete greenhouses in a specific page, the greenhouse get inserted directly to the database

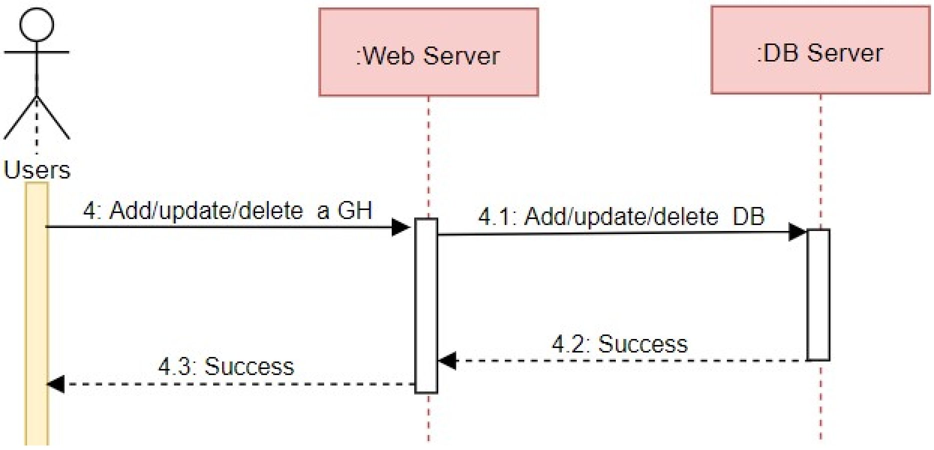


Figure 22 Sequence diagram of the "Add/update/delete a GH" scenario

Step 6 : After adding the greenhouses and linking the robot , the user have to set a configuration or just let it with the default configuration, the role of the configuration is the automatic decision making.

Step 7 : The next step after setting the configuration needed, the user has to create plans for the robot to follow.

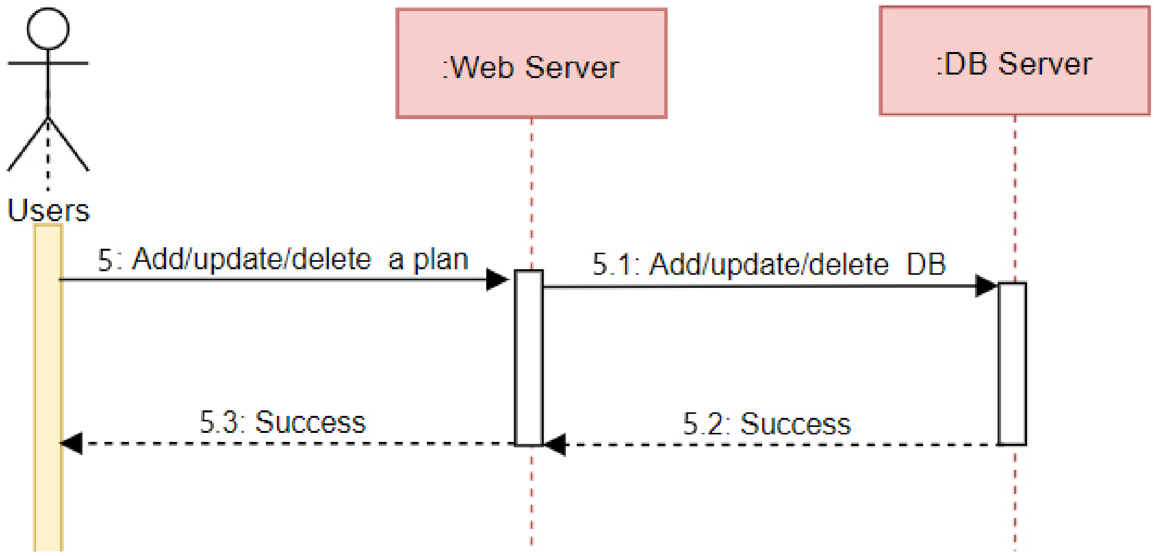


Figure 23 Sequence diagram of the "Add/update/delete a plan" scenario

After all that the job of the user is finished and all what left for the user is to monitor and see the statistics of the greenhouses, and the robot will handle everything from there.

Step 8 : All plans go into a script that runs in DM server, so when it is the right time the DM server uses SubPub server to publish an MQTT message to the robot to start the tour, like the next figure:

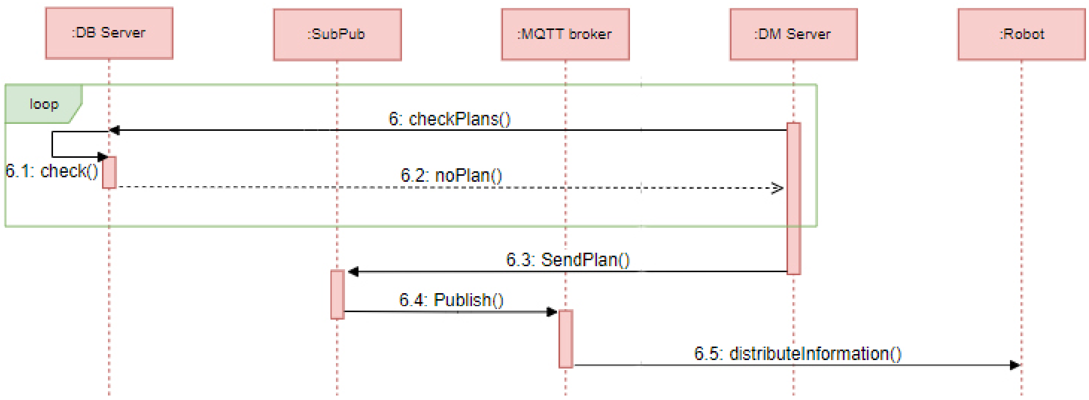


Figure 24 Sequence diagram of the "Checking for a plan" scenario

Step 9 : After receiving the order to start, the robot start navigating through the green houses as shown in the mechanical layer, the navigating will be thro a matrix , each greenhouse has its own x and y.

```
Function GetDistance(Argument AGOne)
      Distance <- sensorGetDistance()
      While distance> AGOne :
            Distance <- sensorGetDistance()
      Return distance
```

Step 10 : When the robot arrives to the door of the greenhouse, it has to get close enough without crushing in the door so in this case we use the ultrasonic sensor that been places in the head of the robot to detect the distance of the door and make the robot stop when it reach 30cm,the next pseudo algorithm will be used in this step and also in the step where the robot get close to the plants

Step 11 : When the robot is stopped next to the door the arduino will connect automatically to the access point on the robot and will send an UDP message to the micro controller on the robot notifying it that the connection is done successfully

Step 12 : After that the robot send an UDP message to the arduino in the greenhouse to open the door of that GH

Step 13 : After the door been opened the GH send an UDP message to robot so it can go to the center of the GH

Step 14 : And Then the robot use the sensors attached to it to get the temperature, humidity and the light and send it to the SubPub:

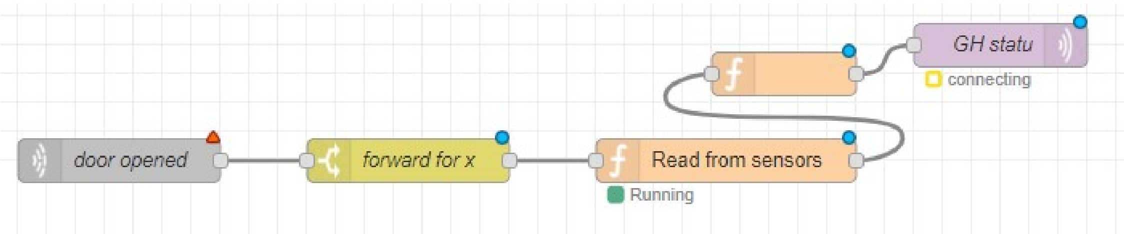


Figure 25 The Flow of sending and sending to the cloud

Step 15 : After the SubPub server receive data from the broker that been published by the robot, in insert it into the DB server to be displayed later to the client by the web server and requests making a Decision from DM server.

Step 16 : The DM server send a query to DB server to get the configuration that been set by the client.

Step 17 : DM server publish commands using SubPub server

Step 18 : The robot receive the commands and send forward them using UDP to the green house

The next diagram will demonstrate from step 14 to step 18:

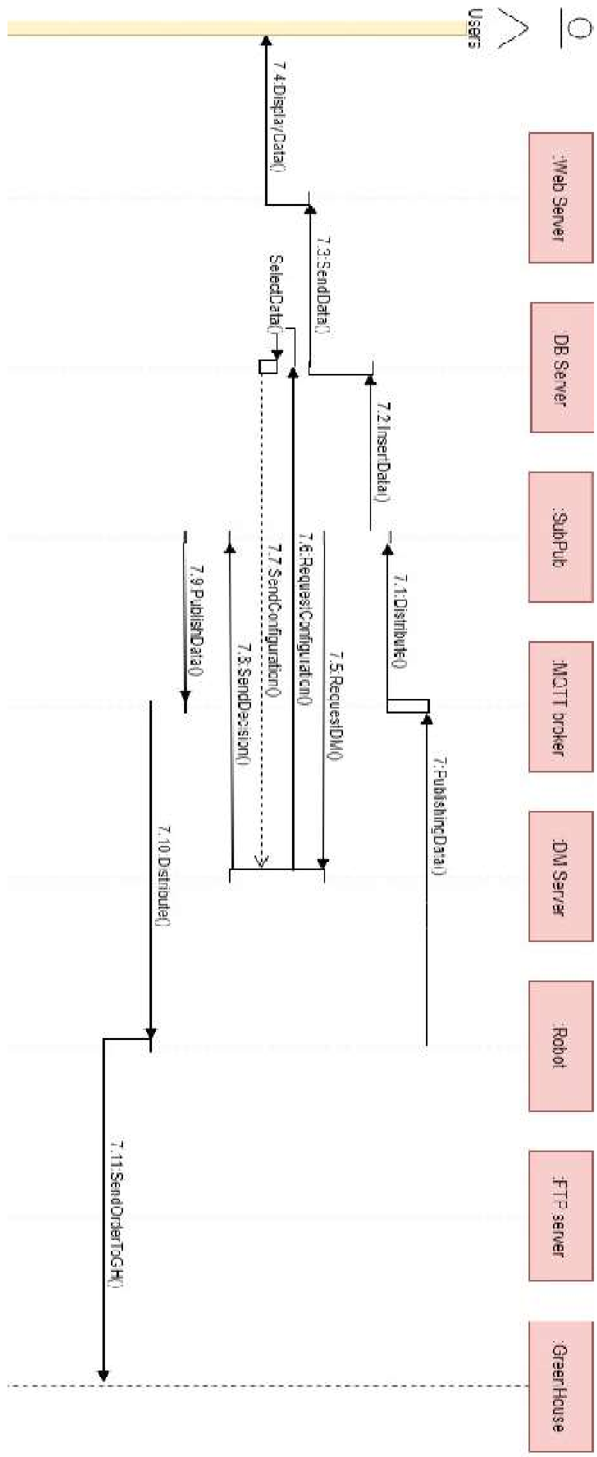


Figure 26 Sensing and communication

Step 19 : The next step it will be detecting and tracking the placement of the plants in the greenhouse and to do so we need to things , the first thing is the mechanical layer of the robot to turn the head as been explained earlier and second thing will be a python script; we will explain this next in this chapter.

And after finding the plant the robot manage to navigate to that object by trying to centralize the square drawn by the script and stop when it is close enough and that's will be by using the ultrasonic sensor just same as been used to stop on the door.

Step 20 : When the robot is facing the plant it will take a picture of the plant and upload it to the FTP server.

Step 21 : The FTP server will send it to the DM server to be treated by a deep learning machine; we will explain this next in this chapter.

Step 22 : After the picture sent by the robot been treated by the deep learning machine it will detect in that plant is healthy or have a disease, and we have too cases;

- The first case: is a healthy plant and in this case the DM server will publish a message using SubPub server saying the plant is healthy and the robot will move on to next plant

  The second case: a sick plant for our deep learning machine it can detect 4 different diseased:

  - leaf Moldmanual
  - bacterial Spot
  - yellow curved
  - tomato mosaic

  In this case the DM server will publish a message using SubPub server notifying the robot that this plant is sick and have to deal with it.

Step 23 : When the robot receive a message that the plant is healthy will redo the step 19 to navigate to the next plant.

Step 24 : If the robot received that this plant is sick , it will use the micro mini pump that is attached to it to spray a chemical product on the plant than move to step 23.

Step 25 : after checking all the plant the robot get back to the center of the GH and go out and send a message to the arduino to close the door then move to the next GH and redo all the steps from step 9.

3.5 Detecting the plant and navigating

Our problem was how to know the placement of the plant in the greenhouse, and we tried to solve this problem with the next pseudo algorithm

```
Begin
    Cap←Sensor_get_distance()
    While  cap>10 Do
        Image← Capture_the_video_stream(Camera()) ;
        V←checkObject(Image) ;
        If V is true then
            Point←Get_XY(image)
            Turn_robot(Point) ;
            Forward(0.2ms) ;
            Cap←Sensor_get_distance()
        Else :
            Turn_robot_head(5°) ;
        endIf

    endWhile

End
```

3.6 Deep Learning

Object detection is a task in computer vision that involves identifying the presence, location, and type of one or more objects in a given photograph.

It is a challenging problem that involves building upon methods for object recognition (e.g. where are they), object localization (e.g. what are their extent), and object classification (e.g. what are they).

The approach involves a single deep convolutional neural network (originally a version of GoogLeNet, later updated and called DarkNet based on VGG) that splits the input into a grid of cells and each cell directly predicts a bounding box and object classification. The result is a large number of candidate bounding boxes that are consolidated into a final prediction by a post-processing step. [29]

The input is an image, this image get divided up a grid of 13 by 13 cells

Each of these cells is responsible for predicting 5 bounding boxes. A bounding box describes the rectangle that encloses an object.

The output a confidence scores that tells us how certain it is that the predicted bounding box actually encloses some object. This score doesn't say anything about what kind of object is in the box, just if the shape of the box is any good.

For each bounding box, the cell also predicts a *class*. This works just like a classifier: it gives a probability distribution over all the possible classes such as:

- Healthy leaf
- leaf Moldmanual
- bacterial Spot
- yellow curved
- tomato mosaic

The confidence score for the bounding box and the class prediction are combined into one final score that tells us the probability that this bounding box contains a specific type of object.

Since there are 13×13 = 169 grid cells and each cell predicts 5 bounding boxes, we end up with 845 bounding boxes in total. It turns out that most of these boxes will have very low confidence scores, so we only keep the boxes whose final score high

From the 845 total bounding boxes we only kept these three because they gave the best results. But note that even though there were 845 separate predictions, they were all made at the same time — the neural network just ran once. [29]

Network designs

The major concept of it is to build a CNN network to predict a (7, 7, 30) tensor. It uses a CNN network to reduce the spatial dimension to 7×7 with 1024 output channels at each location. it performs a linear regression using two fully connected layers to make 7×7×2 boundary box predictions. To make a final prediction, we keep those with high box confidence scores as our final predictions . [29]

The class confidence score for each prediction box is computed as:

```
confidence score = box confidence score × conditional class probability
```

the network has 24 convolutional layers followed by 2 fully connected layers (FC). Some convolution layers use 1 × 1 reduction layers alternatively to reduce the depth of the features maps. For the last convolution layer, it outputs a tensor with shape (7, 7, 1024). The tensor is then flattened. Using 2 fully connected layers as a form of linear regression, it outputs 7×7×30 parameters and then reshapes to (7, 7, 30).[29]

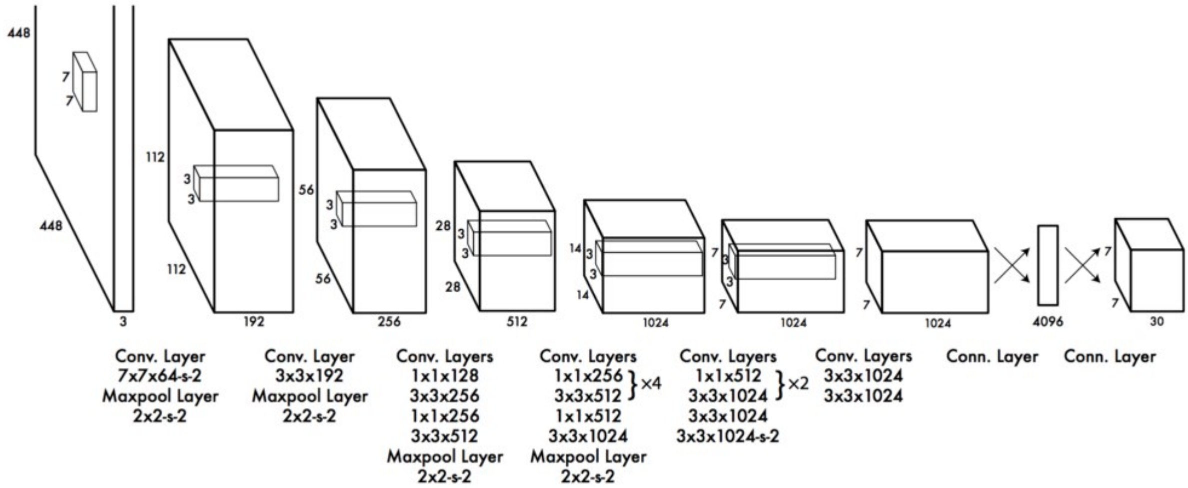


Figure 27 Deep learning network

3.7 Conceptual model of our main database

The following figure shows the conceptual model of our main database.

- A user own one and only one robot
- A robot manage one or more greenhouse
- Each greenhouse can have one or more plan
- Each greenhouse can have one or many states
- Each state have only one and only one action

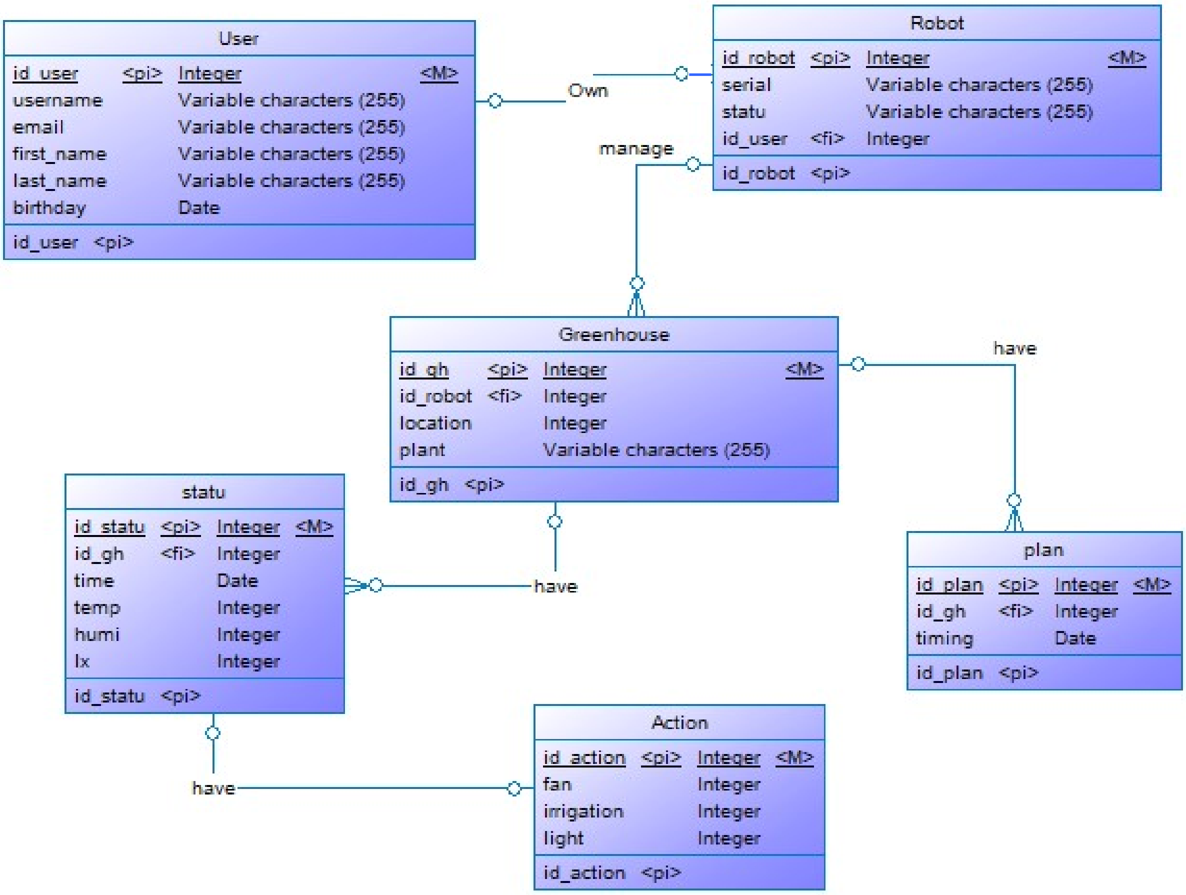


Figure 28 Conceptual model of our main database

3.8 Conclusion

We have introduced a new solution for the implementation of smart mobile garden robot for supervising smart greenhouses using Internet of Things (IoT) technologies and cloud computing, and this solution includes monitoring of greenhouses at remote, automatic decision-making and disease detecting ... etc. In this chapter, we have put some diagrams to further clarify the operation of the system, we saw at first a detailed architecture of our greenhouse monitoring system based on IoT, and we presented each of its components and the relationship between them, and also we have also presented an electronic diagram that explains the electrical operation in the greenhouse.

Chapter 04

Chapter 04

System Implementation

4.1 Introduction

In the third chapter, we explained the design part of our system which is composed of two sides, the client side which represents the monitored greenhouses and the supplier side which represents the six components that are located in the cloud where the applications are hosted by the service provider (SaaS).

In this chapter we will describe the steps we have taken to develop and implement our IoT solution. As a first step, we will present brief definitions of the development languages and tools used in the implementation of our system, and secondly we will present the electronic equipment used for the deployment of the solution, and we will also demonstrate figures and roles of our software and hardware, in this case the software is the web application and the hardware contained both the robot and the smart greenhouse.

4.2 Programming language

There are a lot of programming languages and we had to choose which languages to work with and we have chosen:

4.2.1 Python3

Python is probably the easiest-to-learn and nicest-to-use programming language in widespread use. Python code is clear to read and write, and it is concise without being cryptic. Python is a very expressive language, which means that we can usually write far fewer lines of Python code than would be required for an equivalent application written in, say, C++ or Java.

Python is a cross-platform language: In general, the same Python program can be run on Windows and Unix-like systems such as Linux, BSD, and Mac OS X, Rasbian, simply by copying the file or files that make up the program to the target machine, with no “building” or compiling necessary. It is possible to create Python programs that use platform-specific functionality, but this is rarely necessary since almost all of Python’s standard library and most third-party libraries are fully and transparently cross-platform.[30]

4.2.1.1 Why python

We have chosen python because it is a language useable for all the programming platforms, so we used it for the application and also for the micro controller, and its way easier than a lot of other programming languages

4.2.2 HTML5

HTML5 is a programming language whose acronym stands for Hyper Text Markup Language. It is a system that allows the modification of the appearance of web pages, as well as making adjustments to their appearance. It also used to structure and present content for the web.[31]

4.2.2.1 Why HTML5

The Internet is a very different place than it was in 1999 when the last major update, HTML4.01, was implemented. Technologies exist today that we couldn’t have imagined before the turn of the century. Smart phones, tablets and other mobile devices have introduced new challenges to engineers and software developers. Increased globalization has made the standardization of Internet technology a top priority for everyone with a stake in the world economy. Internet usage worldwide continues to grow year after year and the technology used is projected to evolve at an increasingly faster rate.[32]

4.2.3 CSS3

CSS3 is the latest evolution of the Cascading Style Sheets language and aims at extending CSS2.1. It brings a lot of long-awaited novelties, like rounded corners, shadows, gradients, transitions or animations, as well as new layouts like multicolumn, flexible box or grid layouts. Experimental parts are vendor-prefixed and should either be avoided in production environments, or used with extreme caution as both their syntax and semantics can change in the future.[33]

4.2.4 JQuery

JQuery is a fast, small, and feature-rich JavaScript library. It makes things like HTML document traversal and manipulation, event handling, animation, and Ajax much simpler with an easy-to-use API that works across a multitude of browsers. With a combination of versatility and extensibility, jQuery has changed the way that millions of people write JavaScript.[34]

4.3 Development tools and frameworks

4.3.1 Django

Django is a high-level Python Web framework that encourages rapid development and clean, pragmatic design. Built by experienced developers, it takes care of much of the hassle of Web development, so you can focus on writing your app without needing to reinvent the wheel. It’s free and open source.[35]

4.3.1.1 Why Django

- Django was designed to help developers take applications from concept to completion as quickly as possible.
- Django takes security seriously and helps developers avoid many common security mistakes.
- Some of the busiest sites on the Web leverage Django’s ability to quickly and flexibly scale.

4.3.2 Jinja

Jinja2 is a full featured template engine for Python. It has full Unicode support, an optional integrated sandboxed execution environment, widely used and BSD licensed.[36]

Jnja2 is one of the most used template engines for Python. It is inspired by Django's templating system but extends it with an expressive language that gives template authors a more powerful set of tools. On top of that it adds sandboxed execution and optional automatic escaping for applications where security is important.[36]

4.3.3 Paho MQTT

MQTT is a connectivity protocol designed for M2M. It is an extremely lightweight publish/subscribe messaging transport that is ideal for connecting small devices connected on networks with minimal bandwidth. The Eclipse Paho project is the reference implementation for the MQTT protocol. This webinar will introduce developers to MQTT and then show how you can develop your very first MQTT based application using Paho and the Eclipse IDE.[37]

4.3.4 Eclipse Mosquitto broker

Eclipse Mosquitto is an open source (EPL/EDL licensed) message broker that implements the MQTT protocol versions 5.0, 3.1.1 and 3.1. Mosquitto is lightweight and is suitable for use on all devices from low power single board computers to full servers.

The Mosquitto project also provides a C library for implementing MQTT clients, and the very popular mosquitto_pub and mosquitto_sub command line MQTT clients. Mosquitto is part of the Eclipse Foundation and is an iot.eclipse.org project.[38]

4.3.5 Node-RED

Node-RED is a programming tool for wiring together hardware devices, APIs and online services in new and interesting ways.[39] Node-RED is a flow-based development tool for visual programming developed originally by IBM for wiring together hardware devices, APIs and online services as part of the Internet of Things.

Node-RED provides a web browser-based flow editor, which can be used to create JavaScript functions. Elements of applications can be saved or shared for re-use. The runtime is built on Node.js. The flows created in Node-RED are stored using JSON. Since version 0.14 MQTT nodes can make properly configured TLS connections.

In 2016, IBM contributed Node-RED as an open source JS Foundation project.[40]

4.3.6 OpenCV

(*Open source computer vision*) is a library of programming functions mainly aimed at real-time computer vision. Originally developed by Intel, it was later supported by Willow Garage then Itseez (which was later acquired by Intel). The library is cross-platform and free for use under the open-source BSD license.

OpenCV supports the deep learning frameworks TensorFlow, Torch/PyTorch and Caffe.

4.3.7 TensorFlow

TensorFlow is a Python-friendly open source library for numerical computation that makes machine learning faster and easier

Machine learning is a complex discipline. But implementing machine learning models is far less daunting and difficult than it used to be, thanks to machine learning frameworks—such as Google's TensorFlow—that ease the process of acquiring data, training models, serving predictions, and refining future results.

Created by the Google Brain team, TensorFlow is an open source library for numerical computation and large-scale machine learning. TensorFlow bundles together a slew of machine learning and deep learning (aka neural networking) models and algorithms and makes them useful by way of a common metaphor. It uses Python to provide a convenient front-end API for building applications with the framework, while executing those applications in high-performance C++.[41]

4.3.8 Yolo

'You Only Look Once' is an Object Detection Algorithm. Yolo is an algorithm that uses convolutional neural networks for object detection.

So what's great about object detection? In comparison to recognition algorithms, a detection algorithm does not only predict class labels, but detects locations of objects as well.

And this Algorithm doesn't depend on multiple Neural networks. It applies a single Neural network to the Full Image. This network divides the image into regions and predicts bounding boxes and probabilities for each region. These bounding boxes are weighted by the predicted probabilities.[42]

Here are few Sample output Images

Figure 29 Image with Object Detection by YOLO algorithm with bounding boxes.

4.3.9 Autodesk Fusion 360

Fusion 360 is the first 3D CAD, CAM, and CAE tool of its kind that connects your entire product development process in a single cloud-based platform that works on PC, Mac, and mobile devices. Fusion 360 offers free use to qualifying hobbyist makers through a simple 3-step activation process.

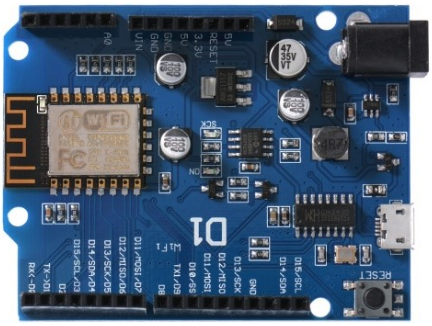
Fusion 360 helps students and educators prepare for the future of design. It's the first 3D CAD, CAM, and CAE tool of its kind, connecting your entire product development process into one cloud-based platform

4.4 Electronic equipment

In this section, we will describe the electronic devices used in our project, we will also give the characteristics of these devices.

4.4.1 Greenhouses side

4.4.1.1 WiFi ESP8266 Development Board WEMOS D1.



WEMOS D1 is a WIFI development board based on ESP8266 12E. The functioning is similar to that of NODEMCU, except that the hardware is built resembling Arduino UNO. The D1 board can be configured to work on Arduino environment using BOARDS MANAGER.[43]

Specification:

- Microcontroller: ESP-8266EX
- Operating Voltage: 3.3V
- Digital I/O Pins: 11
- Analog Input Pins: 1
- Clock Speed: 80MHz/160MHz
- Flash: 4M bytes

4.4.2 4 Channel Arduino Relay Module

This relay module allows you to combine the processing power of the Arduino to devices that use higher current and voltage. It does so by providing four relays that are rated for 7A at either 28VDC or 10A at 125VAC.[44] Each relay has a Normally Open (NO) and a Normally Closed (NC) contact.

4.5 The Robot

4.5.1 Raspberry Pi 3 Model B

The Raspberry Pi 3 Model B is the earliest model of the third-generation Raspberry Pi. It replaced the Raspberry Pi 2 Model B in February 2016. There is also the Raspberry Pi 3 Model B+, the latest product in the Raspberry Pi 3 range.[45]

Specification:

- Quad Core 1.2GHz Broadcom BCM2837 64bit CPU
- 1GB RAM
- BCM43438 wireless LAN and Bluetooth Low Energy (BLE) on board
- 100 Base Ethernet
- 40-pin extended GPIO
- USB 2 ports
- Pole stereo output and composite video port
- Full size HDMI
- CSI camera port for connecting a Raspberry Pi camera
- DSI display port for connecting a Raspberry Pi touchscreen display
- Micro SD port for loading your operating system and storing data
- Upgraded switched Micro USB power source up to 2.5A

4.5.2 Motor Driver Module-L298N

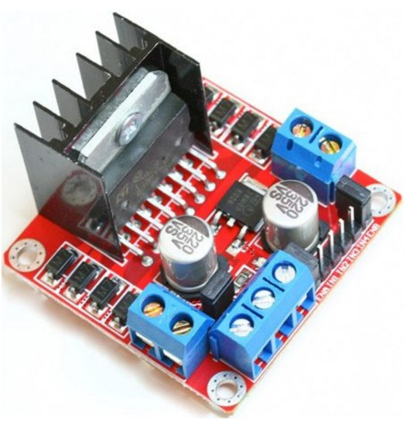


Figure 30 Motor Driver Module-L298N

The L298N is an integrated monolithic circuit in a 15-lead Multiwatt and PowerSO20 packages. It is a high voltage , high current dual full-bridge driver de-signed to accept standard TTL logic level sand drive inductive loads such as relays, solenoids, DC and stepping motors. Two enable inputs are provided to enable or disable the device independently of the in-put signals.

4.5.3 HC-SR04 Ultrasonic Sensor

The Ultrasonic transmitter transmits an ultrasonic wave, this wave travels in air and when it gets objected by any material it gets reflected back toward the sensor this reflected wave is observed by the Ultrasonic receiver module as shown in the picture below.[46]

Figure 31 HC-SR04 Ultrasonic Sensor

HC-SR04 Sensor Features

- Operating voltage: +5V
- Theoretical Measuring Distance: 2cm to 450cm
- Practical Measuring Distance: 2cm to 80cm
- Accuracy: 3mm
- Measuring angle covered: <15°
- Operating Current: <15mA
- Operating Frequency: 40Hz

4.5.4 pi Camera Board v 1.3 (5MP, 1080p)

The Raspberry Pi Camera Board plugs directly into the CSI connector on the Raspberry Pi. It's able to deliver a crystal clear 5MP resolution image, or 1080p HD video recording at 30fps.[47]

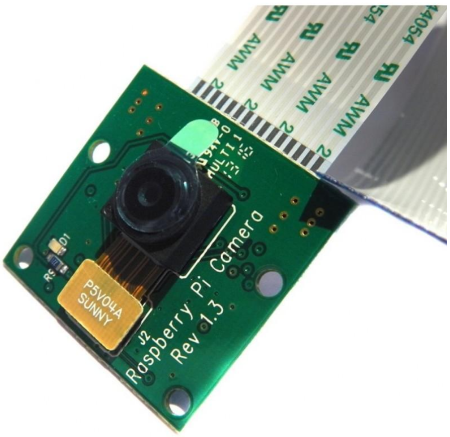


Figure 32 pi Camera Board v 1.3

The Raspberry Pi Camera Board Features:

- Fully Compatible with Both the Model A and Model B Raspberry Pi
- 5MP Omnivision 5647 Camera Module
- Still Picture Resolution: 2592 x 1944
- Video: Supports 1080p @ 30fps, 720p @ 60fps and 640x480p 60/90 Recording
- 15-pin MIPI Camera Serial Interface - Plugs Directly into the Raspberry Pi Board
- Size: 20 x 25 x 9mm
- Weight 3g
- Fully Compatible with many Raspberry Pi cases

4.5.5 DHT22 temperature-humidity sensor

The DHT22 is a basic, low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin (no analog input pins needed). It's fairly simple to use, but requires careful timing to grab data. The only real downside of this sensor is you can only get new data from it once every 2 seconds.[48]

Figure 33 DHT22

TECHNICAL DETAILS

- Low cost
- 3 to 5V power and I/O
- 2.5mA max current use during conversion (while requesting data)

- Good for 0-100% humidity readings with 2-5% accuracy
- Good for -40 to 80°C temperature readings ±0.5°C accuracy
- No more than 0.5 Hz sampling rate (once every 2 seconds)
- Body size 27mm x 59mm x 13.5mm (1.05" x 2.32" x 0.53")
- pins, 0.1" spacing
- Weight (just the DHT22): 2.4g

4.5.6 Micro mini water pump DC

Figure 34 Micro mini water pump DC

Specification:

- DC Voltage: 2.5-6V
- Working current: 130-220mA
- Power: 0.4-1.5W
- Maximum lift: 40-110cm / 15.75"-43.4"
- Flow rate: 80-120L/H
- Outside diameter of water outlet: approx. 7.5mm / 0.3"
- Inside diameter of water outlet: approx. 4.7mm / 0.18"
- Diameter: approx. 24mm / 0.95"
- Length: approx. 45mm / 1.8"
- Height: approx. 33mm / 1.30"
- Wire length: about 15-20cm (red: " + ", black(white): " - ")
- Material: engineering plastic

- Driving mode: brushless DC design, magnetic driving
- Working life: about 200 hours (cannot work continuously)

4.6 The 3D design

We created a 3D model to be printed later and use it for our robot, the next figure will show our design:

Figure 35 Robot 3D model

4.7 The SaaS interface

The SaaS interface is the cloud-hosted web application in which the user can monitor and configure the greenhouses and control the robot.

4.7.1 Main page (homepage)

This is the entrance of our application, it is intended for visitors, customers and the admin and this is where we can see the latest news on technology greenhouses, as the customer can access his account or contact the administrator if there is a problem or ambiguity. The admin also he can connect from this page. And also it has a section for our services and information about our project. The following figure shows the screenshot of the main page web page

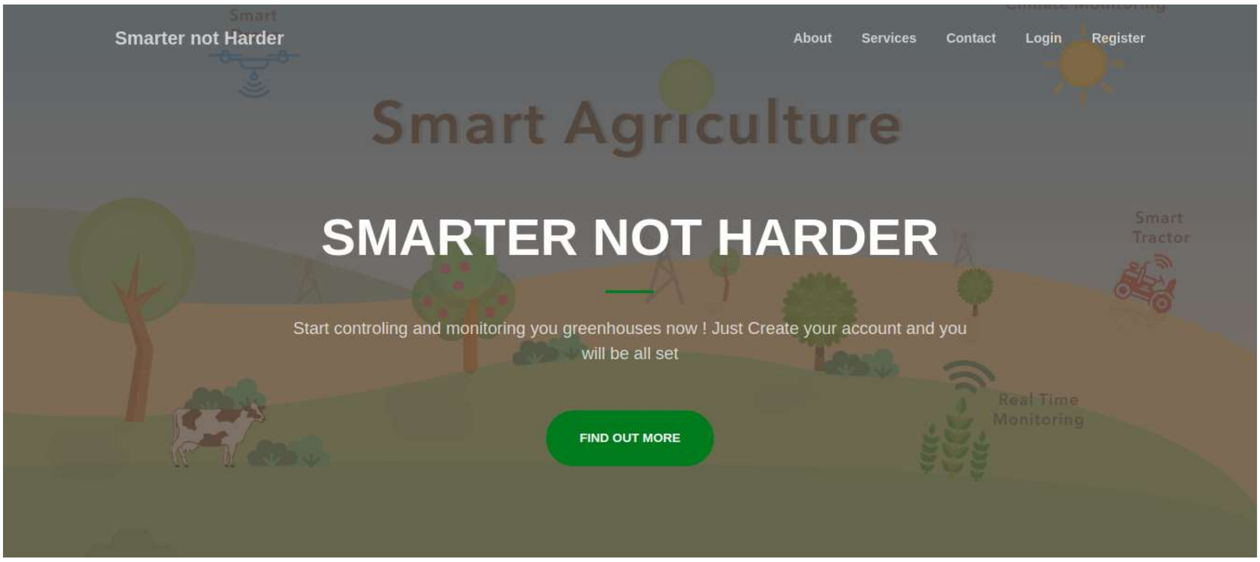


Figure 36 Main page (homepage)

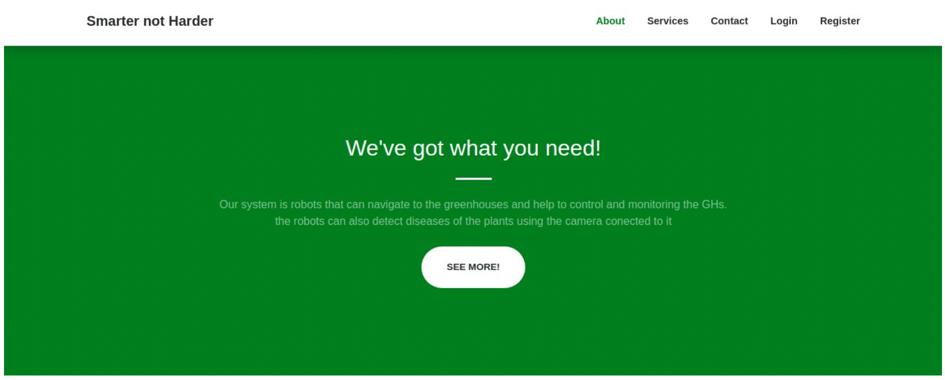


Figure 37 Main page (homepage) Section 1 'about'

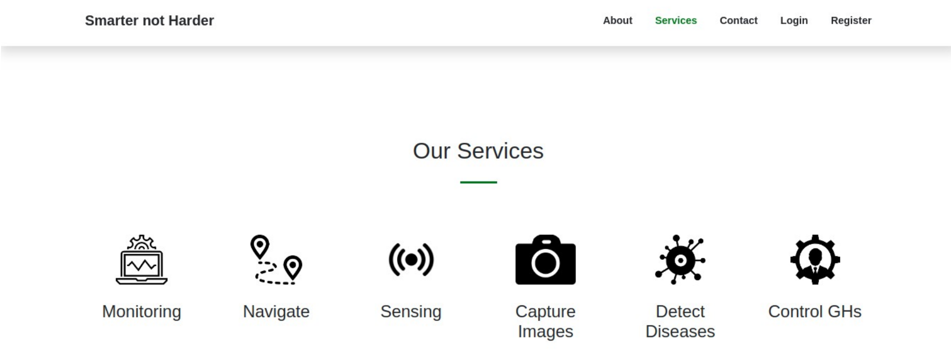


Figure 38 Main page (homepage) Section 2 'Services'

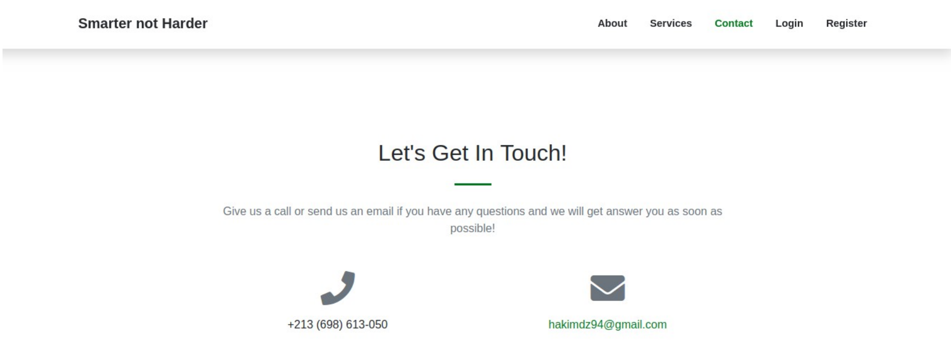


Figure 39 Main page (homepage) Section 3 'Contact'

4.7.2 Authentification page

Authentification page where the users can login into the account so they can monitor and configure their GHs, all what the user need is the user name and the password.

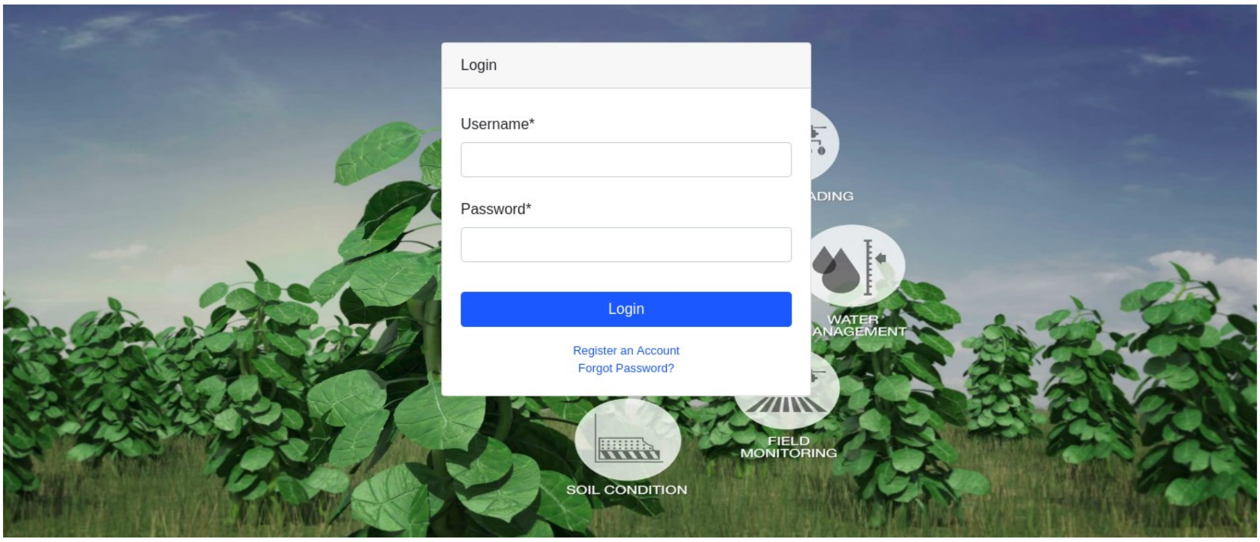


Figure 40 Authentification page

4.7.3 Inscription page

This next page is the page where the new user can create an account in our system. The new user has to fill all the field (username, email, firstname, lastname and password)

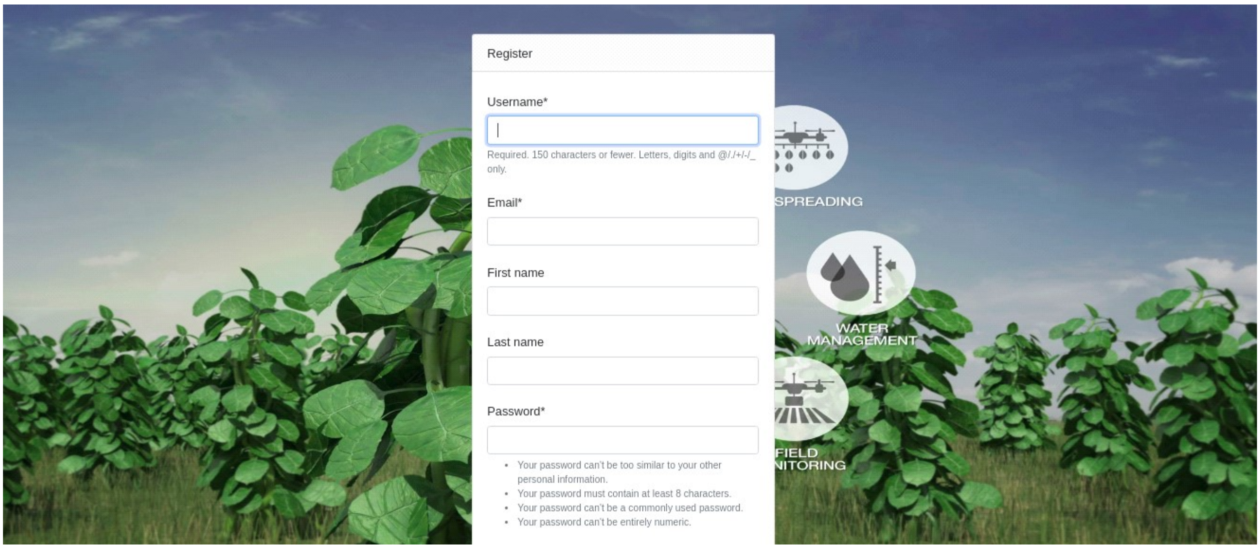


Figure 41 Inscription page

4.7.4 Monitoring Page

This is the web page in which we can see the statue of the robot and we can set and update or delete a plant , and also at this same page u can configure the greenhouses. The following figure shows the screenshot of the monitoring web page.

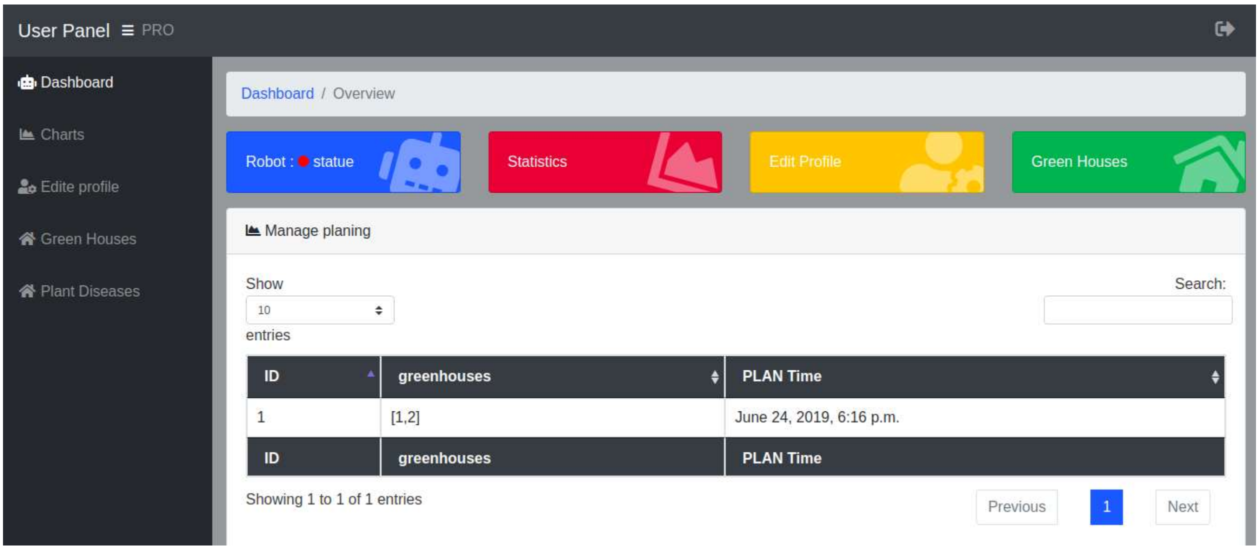


Figure 42 Monitoring Page

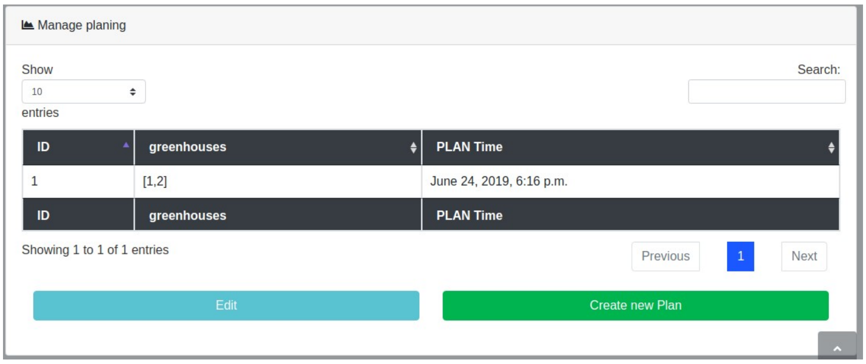


Figure 43 Manage planing

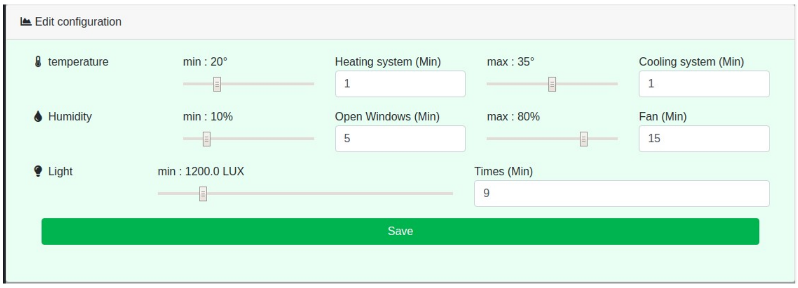


Figure 44 Configure the GHs

4.7.5 GreenHouses page

In this page the user can add or update or delete the greenhouses linked to his account

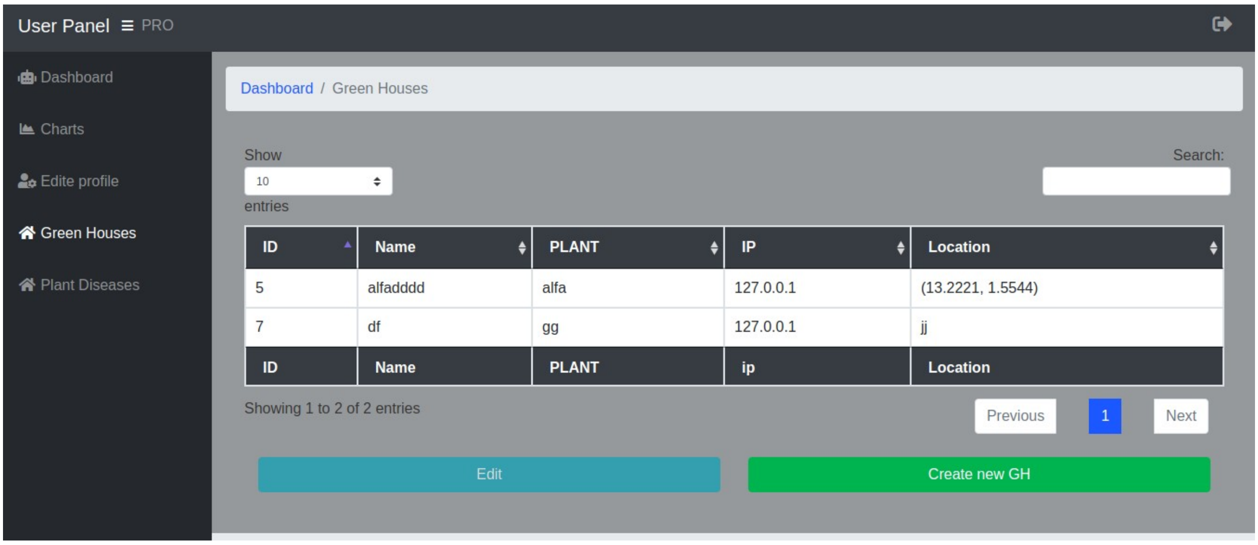


Figure 45 GreenHouse Page

4.7.6 User profile

This web page shows the client's profile, they may see their information or update them, and the following figure shows the screenshot of the client profile web page.

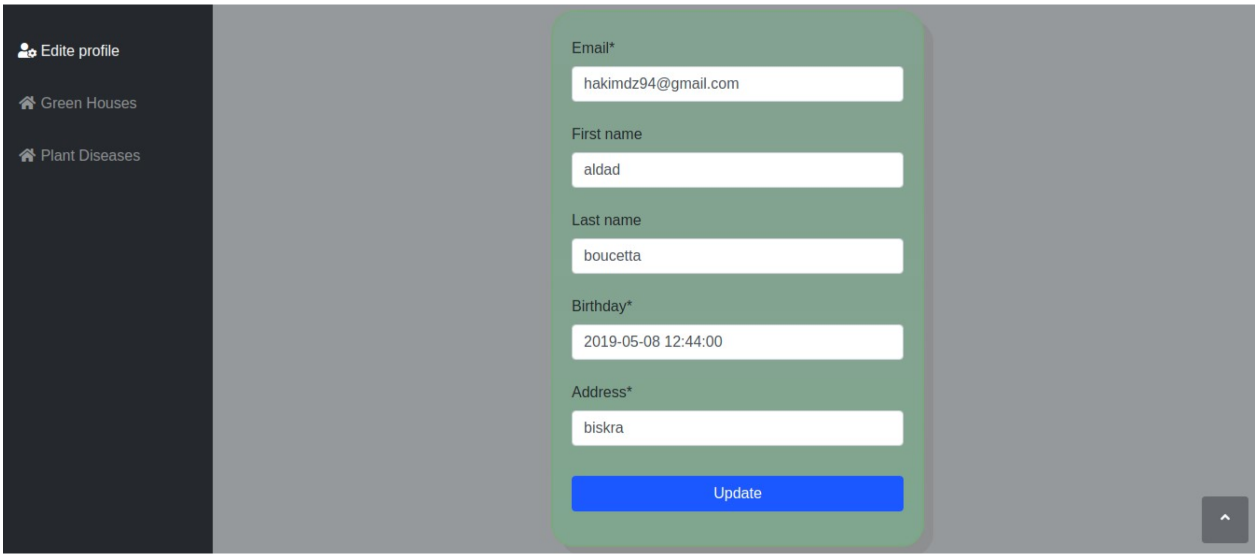


Figure 46 User profile

4.7.7 Link Robot:

When the users login for the first time, they have to link the robot to their account so they can use our application:

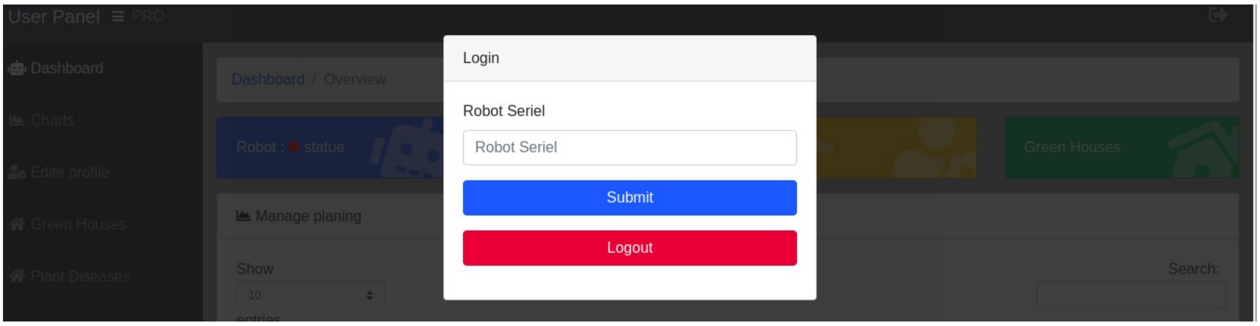


Figure 47 Linking The robot

4.8 Deployment of the solution

4.8.1 Deployment of the GH

In order to realize the proposed solution and using the previously mentioned electronic components plus the actuators (Fan, Lamp, water pump) some actuator works with 220V and some others work with just 12V, the following figures show the box we made that will be placed inside the greenhouse and be controlled by the robot:

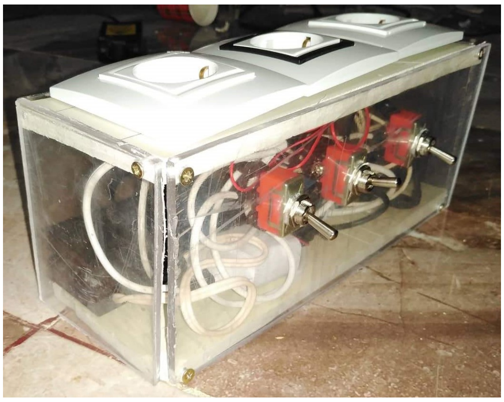


Figure 48 Deployment of the GH

4.8.2 Deployment of the Robot

The next figure will show the robot and it part:

4.9 The Validation of our work

the following table will define the prices for the two works:

We suppose every sink can cover 15 greenhouses so the cost of applying [28] work will be:

Component	Price	Quantity	Total
Raspberry Pi	32.4$	15	486$
Sensor AS-XM1000	95$	15	1425$
Relai 8 Canaux	14$	15	210$
sink SG1000	149$	1	149$
4g lte modem	54$	15	810$
			3080$

Table 4 cost of applying [28] on 15 GH

But for our approach it will cost:

Component	Price	Quantity	Total
Relai 8 Canaux	14$	15	210$
Arduino	10$	15	150$
Robot	234.2$	1	234.2$
			594.2$

Table 5 cost of applyingour approach on 15 GH

Our approach = (PRb) + N×($\sum_{n=1}^{n}$(PCi × Qi))

PRb : Robot Price

[28] approach = $N\times(\sum_{n=1}^{n}(PCi \times Qi))$

Component	Price	Component	Price
Robot	232,4	Raspberry Pi	32,4
Relai 8 Canaux	14	Sensors AS-XM1000	95
Arduino	10	4g lteUSB modem	54
		Relai 8 Canaux	14
		arduino	10
		sink SG1000	149

Table 6 Prices table

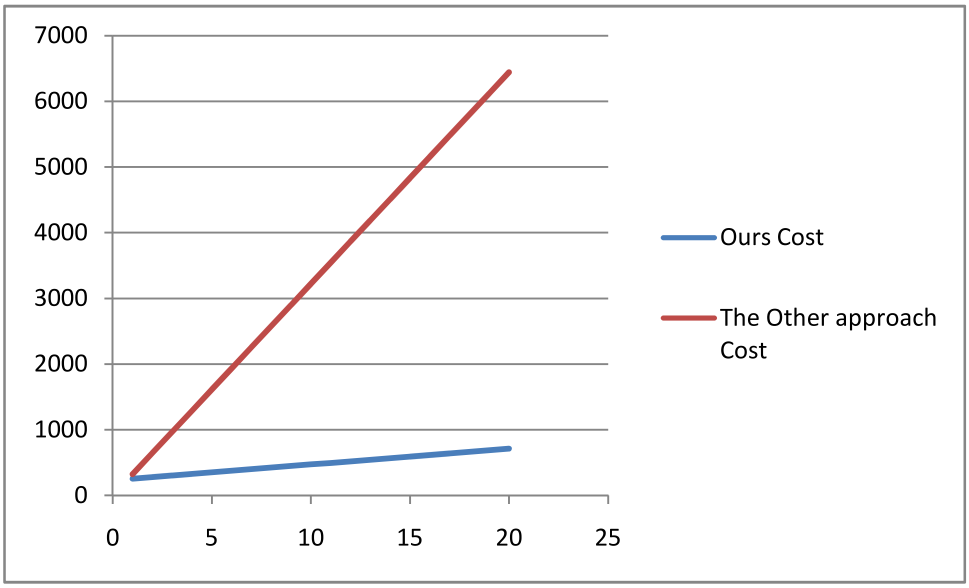


Figure 49 A Comparaison curve of our work and the similar work

4.10 Conclusion

In this chapter, we presented the implementation of our system, we started by presenting the programming language, and after the tools and frameworks used to develop our system, we also presented the electronic devices used in the construction of our project, Web application and realization of the robot and the smart greenhouse

General conclusion

Robotics and Autonomous Systems (RAS) are set to transform global industries. These technologies will have greatest impact on large sectors of the economy with relatively low productivity such as Agri-Food (food production from the farm through to and including manufacturing to the retail shelf).

New technologies are inviting in our daily lives and in many areas, sometimes very surprising. And the field of agriculture is far from being spared. A form of agriculture is developing more and more: it is connected, regardless of the type of production, and requires the use of new technologies such as satellite imagery and computing. Between drones sprinklers and sensors of all kinds, let's start today the discovery of Smart Farming, a method to optimize agricultural yields.

Greenhouse agriculture represents an environment that can be controlled in many aspects, such an environment can be fully regulated in the Internet of Things (IoT) principle. Our vision is a new generation of smart, flexible, robust, compliant, interconnected robotic and autonomous systems working seamlessly alongside their human co-workers in farms and food factories. drive manufacturing productivity and underpin future food security.

Future works

Unfortunately, we have not been able to handle some cases because of the time and limited electronic and computer resources. We would like to improve the solution by working on the navigating of the robot in open space and avoiding the obstacles so we can make a full autonomous robot, and we also like to work on environmental perspective for the robot so it know it environment, the obstacles, the placement of the greenhouses.

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