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Report

Presented to obtain the diploma of academic master in Computer Science

Path: Artificial Intelligence

Smart Irrigation System for Connected Farms

Application to palm farms

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Academic year: 2019/2020

ملخص

إن ري أشجار النخيل لهي عملية حساسة و دقيقة و مكلفة في نفس الوقت من الناحية المادية و البدنية و تأثر على المحصول السنوي بهذه الأشجار و لهذا نقترح في مشروعنا على إستغلال الذكاء الإصطناعي في عملية الري فهو يقوم بتحديد الوقت و كمية المياه اللازمتين لري المزرعة و في إستطاعته التحكم في ري عدد كبير من أشجار النخيل و هذا ما يسهل على المزارعين لترشيد إستهلاك المياه والطاقة وتحسين جودة منتجاتهم.

Summary

Irrigation of palm trees is a, delicate and costly process at the same time from a financially and physical point of view and affects the annual yield of these trees, for this we suggest in our project the exploitation of artificial intelligence in the irrigation process as it determines the time and amount of water needed to irrigate the farm and control the irrigation of a large number of palm trees, which makes it easier for farmers to rationalize water and energy consumption and improve the quality of their products.

Résumé

L'irrigation des palmiers est un processus, délicat et coûteux à la fois d'un point de vue financier et physique, aussi ça affecte le rendement annuel de ces arbres, pour cela nous proposons dans notre projet l'exploitation de l'intelligence artificielle dans le processus d'irrigation dans le but de déterminer le temps et la quantité d'eau nécessaires pour irriguer la ferme et contrôler l'irrigation d'un grand nombre de palmiers, ce qui permet aux agriculteurs de rationaliser plus facilement la consommation d'eau et d'énergie et d'améliorer la qualité de leurs produits.

Thanks

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.

I would like to express my gratitude to the friends and colleagues who gave me their moral and intellectual support throughout my journey.

A big thank you to my parents for encouraging me and for supporting me morally every day in the construction of this memoir.

Without them, I would not be here.

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General Introduction

The world's population is assumed to be nearly 10 billion by 2050, boosting agricultural order-in a situation of humble financial development by somewhere in the range of 50% contrasted with 2013 (FAO, 2017). At present, about 37.7% of total land surface is used for crop production. From employment generation to contribution to National Income, agriculture is important. It is contributing a significant portion in the economic prosperity of the developed nations and is playing an active part in the economy of the developing countries as well. The augmentation of agriculture has resulted in a significant increase in the income of the rural community. Thus, placing a greater emphasis on agricultural sector will be rational and apposite. For countries, like Algeria, the agricultural sector accounts for 12% of GDP. Development in the agricultural sector will boost the rural development, further leading toward rural transformation and eventually resulting in the structural transformation. [1]

A review of the literature shows that various automation programs have been developed to increase product efficiency and ensure more efficient use of water. In the studies in which different methods and technologies were used, wireless sensor networks and telemetry systems were used to develop automation programs, control units were determined from meteorological data obtained from the soil and environment (air/soil moisture, air/soil temperature and wind speed), evaporation rates were determined and irrigation levels were established by processing the data with fuzzy logic and artificial neural networks (ANNs). In the studies that used tensiometers and moisture sensors , irrigation levels were determined by moisture values. This method is accurate, as it provides the soil with water equal to the amount used by the plant. However, it is necessary to irrigate constantly, due to the increased evaporation during daylight hours, when the temperature is high.

Algeria has about 18.53 million palm trees, and this is in a total area of 167,663 hectares, and they are concentrated in desert areas in which there is a scarcity in the amount of water suitable for irrigation. Irrigation is a sensitive process and must be studied because it affects the quantity and quality of the product that is considered the income of many Algerian families.

This is what made us aim to use artificial intelligence in the irrigation process to contribute to reducing some of the burdens on farmers, which are represented in the scarcity of suitable water for irrigation, energy connections and the efforts made in the process, and this is by introducing information technology and artificial intelligence To avoid wasting water and reduce energy costs and the associated expenses.

This Master thesis is organized in four chapters, the first chapter contains generalities on the Internet of things, and the second chapter contains some related works in the field of irrigation in a smart way, the third chapter contains the design of our system and the illustrative diagrams of the proposed smart irrigation system for palm trees. Finally, in the fourth chapter we present the programming languages used, as well as an explanation of the artificial intelligence programming used to develop our project

Chapter 01

Generalities on the Internet of Things (IOT)

Chapter 01

Generalities on the Internet of Thing

1.1 Introduction

The IOT concept was coined by a member of the Radio Frequency Identification (RFID) development community in 1999, and it has recently become more relevant to the practical world largely because of the growth of mobile devices, embedded and ubiquitous communication, cloud computing and data analytics.

Imagine a world where billions of objects can sense, communicate and share information, all interconnected over public or private Internet Protocol (IP) networks. These interconnected objects have data regularly collected, analyzed and used to initiate action, providing a wealth of intelligence for planning, management and decision making. This is the world of the Internet of Things (IOT).

1.2 History of Iot

• The first telemetry system was rolled out in Chicago way back in 1912. It is said to have used telephone lines to monitor data from power plants.[2]

• Telemetry expanded to weather monitoring in the 1930s, when a device known as a radiosonde became widely used to monitor weather conditions from balloons.

• In 1957 the Soviet Union launched Sputnik, and with it the Space Race. This has been the entry of aerospace telemetry that created the basis of our global satellite communications today.

• Broad adoption of M2M technology began in the 1980s with wired connections for SCADA (supervisory control and data acquisition) o the factory floor and in home and business security systems.

• In the 1990s, M2M began moving toward wireless technologies. ADEMCO built their own private radio network to address intrusion and smoke detection because budding cellular connectivity was too expensive.[2]

• In 1995, Siemens introduced the first cellular module built for M2M.[2]

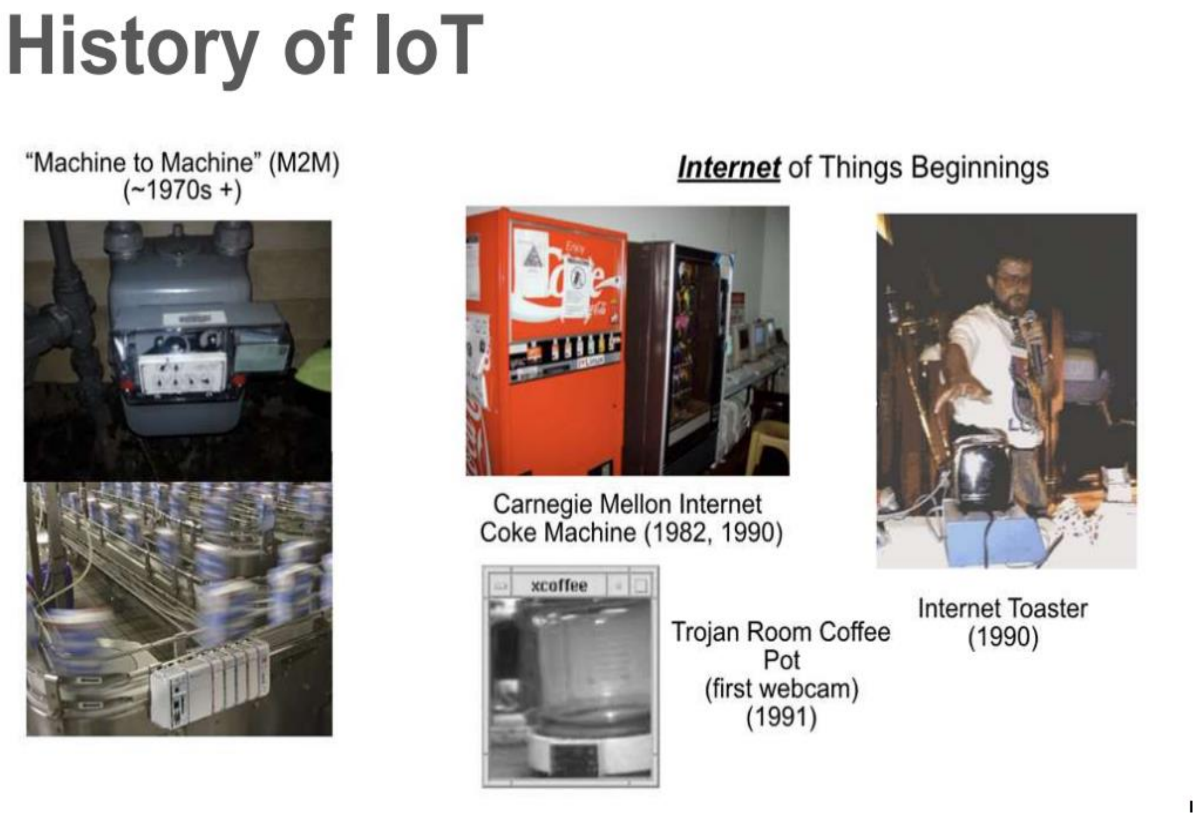


Figure 1. 1: The stages of the internet of Things [2]

1.3 Definition of IoT

Definition 1

The Internet of Tings (IoT) refers to uniquely identifiable objects and their virtual representations in an Internet-like structure. [2]

Definition 2

The Internet of Things (IoT) is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. [3]

Definition 3

The Internet of Tings (IoT) can be viewed as a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies (ICT). [2]

CISCO Definition

The Internet of Things (IoT) is the network of physical objects accessed through the Internet, as defined by technology analysts and visionaries. These objects contain embedded technology to interact with internal states or the external environment. In other words, when objects can sense and communicate, it changes how and where decisions are made, and who makes them. [sisco]

Things

Things are objects of the **physical world** (physical things) or of the **information world** (virtual world) which are capable of being identified and integrated into communication networks. Things have associated information, which can be static and dynamic. [2]

Physical things: exist in the physical world and are capable of being sensed, actuated and connected. Examples of physical things include the surrounding environment, industrial robots, goods and electrical equipment.[2]

Virtual things: exist in the information world and are capable of being stored, processed and accessed. Examples of virtual things clude multimedia content and application softwar.[2]

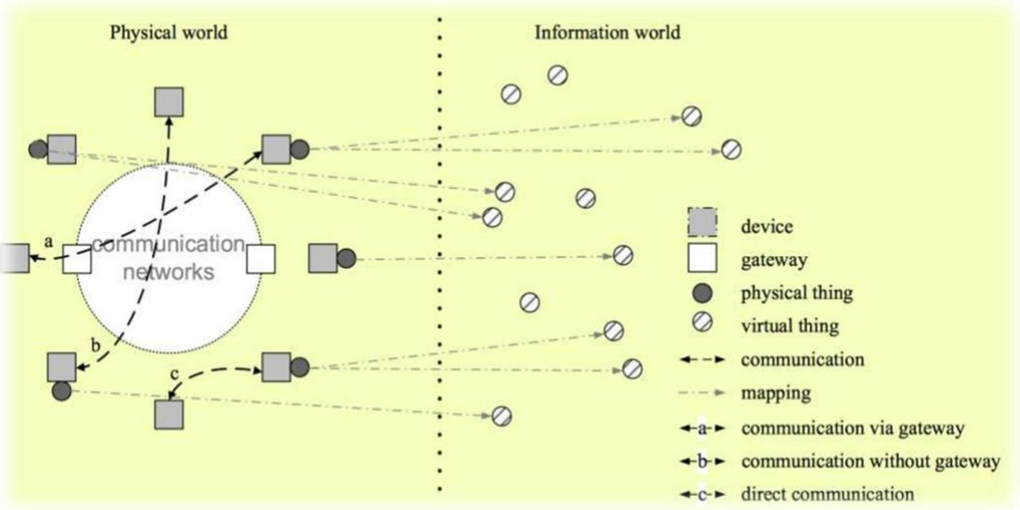


Figure 1. 2: Physical things/ Information word [2]

Any-Time/Place/Thing

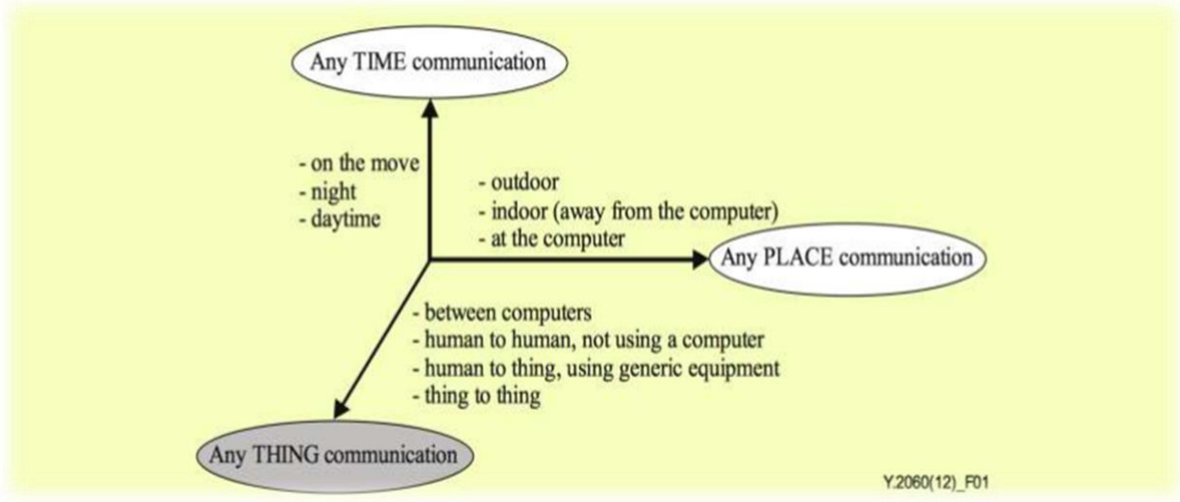


Figure 1. 3: Any Time/Place/Thing communication [2]

1.3.1 IoT architecture building blocks

While every IoT system is different, the foundation for each Internet of Things architecture as well as its general data process flow is roughly the same. First of all, it consists of the Things, which are objects connected to the Internet which by means of their embedded sensors and actuators are able to sense the environment around them and gather information that is then passed on to IoT gateways. The next stage consists of IoT data acquisition systems and gateways that collect the great mass of unprocessed data, convert it into digital streams, filter and pre-process it so that it is ready for analysis. The third layer is represented by edge devices responsible for further processing and enhanced analysis of data. This layer is also where visualization and machine learning technologies may step in. After that, the data is transferred to data centers which can be either cloud-based or installed locally. This is where the data is stored, managed and analyzed in depth for actionable insights. [6]

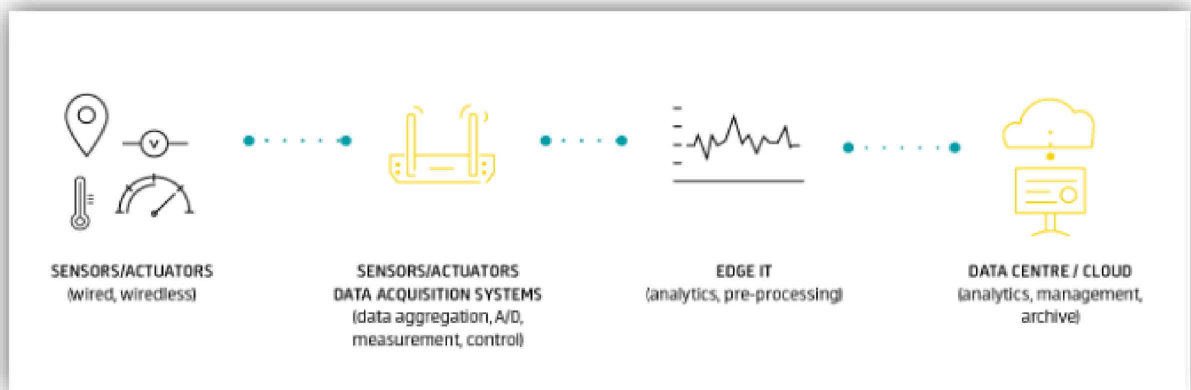


Figure 1. 4: architecture of internet of things [6]

1.3.2 Things, sensors and controllers

As the basis for every IoT system, connected devices are responsible for providing the essence of the Internet of Things which is the data. To pick up physical parameters in the outside world or within the object itself, they need sensors. These can be either embedded in the devices themselves or implemented as standalone objects to measure and collect telemetry data. For an example, think of agricultural sensors whose task is to measure parameters such as air and soil temperature and humidity, soil pH levels or crop exposure to sunlight. [6]

Another indispensable element of this layer is the actuators. Being in close collaboration with the sensors, they can transform the data generated by smart objects into physical action. Let's imagine a smart watering system with all the necessary sensors in place. Based on the input provided by the sensors, the system analyses the situation in real time and commands the actuators to open selected water valves located in places where soil humidity is below the set value. The valves are kept open until the sensors report that the values are restored to default. Obviously, all of this happens without a single human intervention.[6]

What is also important is that the connected objects should not only be capable of communicating bidirectional with their corresponding gateways or data acquisition systems, but also being able to recognize and talk to each other to gather and share information and collaborate in real time to leverage the value of the whole deployment. In case of resource-constrained and battery-operated devices particularly, achieving this is not an easy task since such communication requires lots of computing power and consumes precious energy and bandwidth. Therefore, a robust architecture can only enable effective device management when it uses fit-for-purpose, secure and lightweight communication protocols, such as Lightweight M2M which has become a leading standard protocol for the management of low power lightweight devices which are typical for many IoT use cases. [6]

Figure 1. 5: architecture of sensors and controllers [6]

1.3.3 Gateways and data acquisition

Although this layer still functions in close proximity with sensors and actuators on given devices, it is essential to describe it as a separate IoT architecture stage as it is crucial for the processes of data collection, filtering and transfer to edge infrastructure and cloud-based platforms. Given the massive volume of input and output that million-device deployments may generate capabilities for the aggregation, selection and transportation of data should be in the spotlight. As intermediaries between the connected things and the cloud and analytics, gateways and data acquisition systems provide the necessary connection point that ties the remaining layers together. [6]

Sitting at the verge of the worlds of OT and IT, gateways facilitate communication between the sensors and the rest of the system by converting the sensor data into formats that are easily transferable and usable for the other system components down the line. What's more, they are able to control, filter and select data to minimize the volume of information that needs to be forwarded to the cloud, which positively affects network transmission costs and response times. Thus, gateways provide a place for the local preprocessing of sensor data which is squeezed into useful bundles ready for further processing.[6]

Another aspect that the gateways support is security. Because the gateways are responsible for managing the information flow in both directions, with the help of proper encryption and security tools they can prevent IoT cloud data leaks as well as reduce the risk of malicious outside attacks on IoT devices.[6]

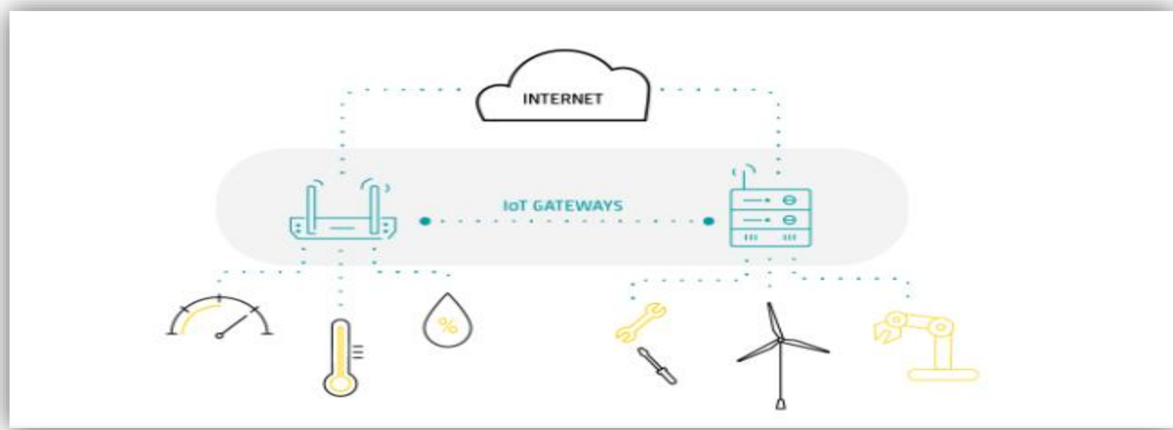


Figure 1. 6: architecture of Gateways between things [6]

1.3.4 Edge analytics

While not being an inevitable component of every IoT architecture, edge devices can bring significant benefits especially to large-scale IoT projects. In the face of limited accessibility and data transfer speed of the IoT cloud platforms, edge systems can provide quicker response times and more flexibility in the processing and analysis of IoT data. As speed of data analysis is key in some industrial internet of things applications, edge computing has recently seen a dramatic increase in popularity among Industrial Internet of Things ecosystems. [6]

As edge infrastructure can be located closer to the data source in physical terms, it is easier and quicker for it to act on the IoT material in real time and provide output in the form of instant actionable intelligence. In this scenario, only the larger chunks of data which really need the power of the Cloud to be processed are forwarded there. By minimizing network exposure, security can be significantly enhanced, while reduced power and bandwidth consumption contributes to more efficient leveraging of business resources.[6]

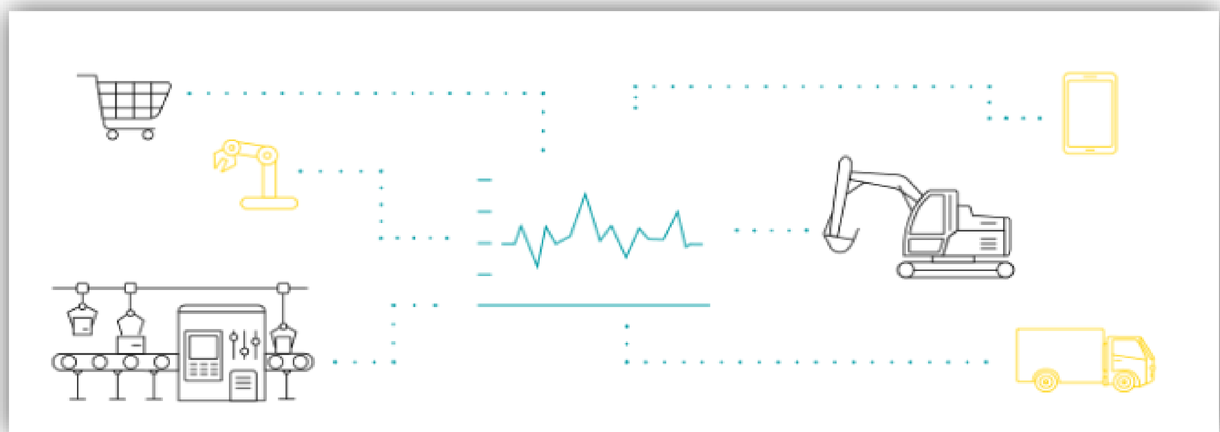


Figure 1. 7: architecture of Edge analytics [6]

1.3.5 Data centre / Cloud platform

If sensors are neurons and the gateway is the backbone of IoT, then the cloud is the brain in the Internet of Things body. Contrary to edge solutions, a data center or a cloud-based system is designed to store, process and analyses massive volumes of data for deeper insights using powerful data analytics engines and machine learning mechanisms which edge systems would never be able to support. [6]

Having seen increased adoption (especially in Industrial IoT architecture) over the past several years, cloud computing contributes to higher production rates, reduction of unplanned downtime and energy consumption and many other business benefits.

If furnished with proper user application solutions, the cloud can provide business intelligence and presentation options that help humans interact with the system, control and monitor it and make informed decisions on the basis of reports, dashboards and data viewed in real time. [6]

Figure 1. 8: Data Center [6]

1.4 Intelligence in IoT

Ambient intelligence and autonomous control are not part of the original concept of the Internet of things. Ambient intelligence and autonomous control do not necessarily require Internet structures, either. However, there is a shift in research (by companies such as Intel) to integrate the concepts of the IoT and autonomous control, with initial outcomes towards this direction considering objects as the driving force for autonomous IoT.A promising approach in this context is deep reinforcement learning where most of IoT systems provide a dynamic and interactive environment.Training an agent (i.e., IoT device) to behave smartly in such an environment cannot be addressed by conventional machine learning algorithms such as supervised learning. By reinforcement learning approach, a learning agent can sense the environment's state (e.g., sensing home temperature), perform actions (e.g., turn HVAC on or off) and learn through the maximizing accumulated rewards it receives in long term. [3]

1.5 Applications of IoT

The extensive set of applications for IoT devices is often divided into consumer, commercial, industrial, and infrastructure spaces. [3]

1.5.1 Consumer applications

A growing portion of IoT devices are created for consumer use, including connected vehicles, home automation, wearable technology, connected health, and appliances with remote monitoring capabilities. [3]

1.5.1.1 Smart home

IoT devices are a part of the larger concept of home automation, which can include lighting, heating and air conditioning, media and security systems. Long-term benefits could include energy savings by automatically ensuring lights and electronics are turned off.

A smart home or automated home could be based on a platform or hubs that control smart devices and appliances. For instance, using Apple's Home Kit, manufacturers can have their home products and accessories controlled by an application in iOS devices such as the iPhone and the Apple Watch. [3]

1.5.1.2 Elder care

One key application of a smart home is to provide assistance for those with disabilities and elderly individuals. These home systems use assistive technology to accommodate an owner's specific disabilities. Voice control can assist users with sight and mobility limitations while alert systems can be connected directly to cochlear implants worn by hearing-impaired users. They can also be equipped with additional safety features. [3]

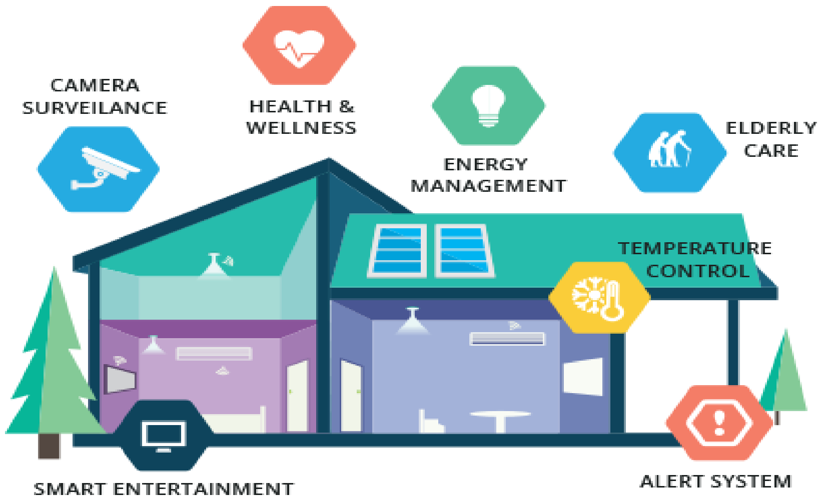


Figure 1. 9: controllers to help the elderly [5]

1.5.2 Commercial application

1.5.2.1 Medical and healthcare

The Internet of Medical Things (IoMT), (also called the Internet of health things), is an application of the IoT for medical and health related purposes, data collection and analysis for research, and monitoring. The IoMT has been referenced as "Smart Healthcare", as the technology for creating a digitized healthcare system, connecting available medical resources and healthcare services. [3]

1.5.2.2 Transportation

The IoT can assist in the integration of communications, control, and information processing across various transportation systems. Application of the IoT extends to all aspects of transportation systems (i.e. the vehicle, the infrastructure, and the driver or user). Dynamic interaction between these components of a transport system enables inter- and intra-vehicular communication, smart traffic control, smart parking, electronic toll collection systems, logistics and fleet management, vehicle control, safety, and road assistance. [3]

Figure 1. 10: internet of things in the medical [4]

1.5.2.3 V2X communications

In vehicular communication systems, vehicle-to-everything communication (V2X), consists of three main components: vehicle to vehicle communication (V2V), vehicle to infrastructure communication (V2I) and vehicle to pedestrian communications (V2P). V2X is the first step to autonomous driving and connected road infrastructure. [3]

1.5.2.4 Building and home automation

IoT devices can be used to monitor and control the mechanical, electrical and electronic systems used in various types of buildings (e.g., public and private, industrial, institutions, or residential) in home automation and building automation systems. In this context, three main areas are being covered in literature:

- The integration of the Internet with building energy management systems in order to create energy efficient and IOT-driven "smart buildings".
- The possible means of real-time monitoring for reducing energy consumption and monitoring occupant behaviors.
- The integration of smart devices in the built environment and how they might to know how to be used in future applications. [3]

1.5.3 Industrial applications

Also known as IIoT, industrial IoT devices acquire and analyze data from connected equipment, (OT) operational technology, locations and people. Combined with operational technology (OT) monitoring devices, IIOT helps regulate and monitor industrial systems. [3]

1.5.3.1 Manufacturing

The IoT can realize the seamless integration of various manufacturing devices equipped with sensing, identification, processing, communication, actuation, and networking capabilities. Based on such a highly integrated smart cyber-physical space, it opens the door to create whole new business and market opportunities for manufacturing. [3]

1.5.3.2 Agriculture

There are numerous IoT applications in farming such as collecting data on temperature, rainfall, humidity, wind speed, pest infestation, and soil content. This data can be used to automate farming techniques, take informed decisions to improve quality and quantity, minimize risk and waste, and reduce effort required to manage crops. For example, farmers can now monitor soil temperature and moisture from afar, and even apply IoT-acquired data to precision fertilization programs. [7]

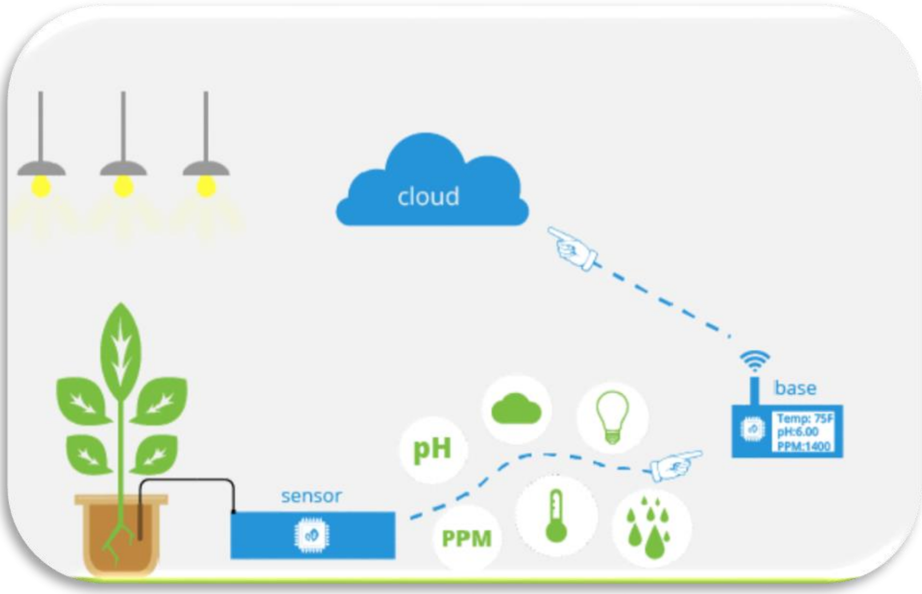


Figure 1. 11: internet of things in the agriculture [7]

1.5.4 Infrastructure applications

Monitoring and controlling operations of sustainable urban and rural infrastructures like bridges, railway tracks and on- and offshore wind-farms is a key application of the IoT. The IoT infrastructure can be used for monitoring any events or changes in structural conditions that can compromise safety and increase risk. [3]

1.5.4.1 Metropolitan scale deployments

There are several planned or ongoing large-scale deployments of the IoT, to enable better management of cities and systems. For example, Songdo, South Korea, the first of its kind fully equipped and wired smart city, is gradually being built, with approximately 70 percent of the business district completed as of June 2018. Much of the city is planned to be wired and automated, with little or no human intervention. [3]

1.5.4.2 Energy management

Significant numbers of energy-consuming devices (e.g. switches, power outlets, bulbs, televisions, etc.) already integrate Internet connectivity, which can allow them to communicate with utilities to balance power generation and energy usage and optimize energy consumption .

1.5.4.3 Environmental monitoring

Environmental monitoring applications of the IoT typically use sensors to assist in environmental protection by monitoring air or water quality, atmospheric or soil conditions, and can even include areas like monitoring the movements of wildlife and their habitats. [3]

1.6 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.

Chapter 2

Smart Agriculture and Related Works

Chapter 2

Smart Agriculture and Related Works

2.1 Introduction

Efficient utilization of water is a challenging task especially for places where availability of water is a major concern. For gaining high yields, one has to irrigate the field when needed or we can say that the exact amount and time of irrigation must be known. Nowadays with the help of new innovations in technology, we are living in the world of advanced irrigation systems called "smart irrigation." The word smart means, the sensors are able to sense the water requirements in plants. This ability is achieved by combining multiple technologies viz. automation, sensors, and knowledge (AI). Even though these systems are not costly in nature, due to lack of awareness, most of the farmers are adopting a traditional way of irrigation which results in inefficient utilization of water. [12]

In this second chapter we will first present the use of information technology in the agricultural sector, in order to illustrate the impact of artificial intelligence technologies and IoT on intelligent agriculture. Next, we present some works and studies related to the monitoring of the Internet of Things in the field of agriculture. Finally, we will discuss a comparison between these works and extract the key points that an IoT in intelligent agriculture should have.

2.2 The use of water in agriculture

Water use in agriculture is at the core of any discussion of water and food security. Agriculture accounts for, on average, 70 percent of all water withdrawals globally, and an even higher share of "consumptive water use" due to the evapotranspiration requirements of crops. Worldwide, over 330 million hectares are equipped for irrigation. Irrigated agriculture represents 20 percent of the total cultivated land, but contributes 40 percent of the total food produced worldwide.[15]

Competition for water resources is expected to increase in the future, with particular pressure on agriculture. Significant shifts of inter-sectoral water allocations will be required to support continued economic growth. Due to population growth, urbanization, industrialization, and climate change, improved water use efficiency will need to be matched by reallocation of as much as 25 to 40% of water in water stressed regions, from lower to higher productivity and employment activities. In most cases, this reallocation is expected to come from agriculture, due to its high share of water use. The movement of water will need to be both physical and virtual. Physical movement of water can occur through changes in initial allocations of surface and groundwater resources as well as conveyance of water 'sales', mainly from agricultural to urban, environmental, and industrial users. Water can also move virtually as the production of water intensive food, goods, and services is concentrated in water abundant localities and is traded to water scarce localities. [16]

At the same time, water in agriculture will continue to play a critical role in global food security. Population is expected to increase to over 10 billion by 2050, and whether urban or rural, this population will need food and fiber for its basic needs. Combined with the increased consumption of calories and more complex foods, which accompanies income

growth in much of the developing world, it is estimated that agricultural production will need to expand 70% by 2050. If this expansion is not to come at the expense of massive land conversions and the consequent impact on carbon emissions, agriculture will have to intensify. Given that irrigated agriculture is, on average, at least twice as productive per unit of land, provides an important buffer against increasing climate variability, and allows for more secure crop diversification, it is certain that irrigation will continue to play a key role in ensuring global food and nutrition security. [16]

Figure 2. 1: Irrigation of crops [10]

The above projections for both water and food security appear, at first look, to be contradictory, On one hand, there is a need to use less water in agriculture, but on the other hand, more intensive use of water in agriculture is a key element of sustainable intensification of food production. Resolving this apparent quandary requires a thorough reconsideration of how water is managed in the agricultural sector, and how it can be repositioned in the broader context of overall water resources management and water security. [16]

2.3 Precision Farming /Agriculture

The aim of precision agriculture (PA) is to increase yield production as well as quality by simultaneously reducing the overall cost and environmental pollution. The quantity and quality of a crop depend on many parameters such as soil, weather, irrigation, etc. So, there is a requirement to monitor all these parameters at a regular interval of time. Traditional monitoring techniques are not adequate in accurate and efficient monitoring of these parameters.[12]

So, there is vital demand for an automated system which can perform monitoring of parameters in an effective way. In modern era, proximity sensing and remote sensing dominate the field of agriculture and effectively monitor a plethora of parameters required for better prediction and planning of agricultural practices. Proximity sensing specifically deals with soil using high-resolution data. Remote sensing provides the geographical sensing of fields using various sensors. Thermal remote sensing provides some additional information such as temperature, water status, etc. It also helps us in getting many vegetation indices. Many researchers attempted to present several vegetation indices on the basis of various parameters. Xue and Su presented a systematic reviewed of many vegetation indices. AI in collaboration with these techniques can provide cost-effective solutions for PA.[12]

Figure 2. 2: Palm watering process [11]

2.3.1 Emerging technologies

Precision agriculture is an application of breakthrough digital farming technologies. Over $4.6 billion has been invested in agriculture tech companies—sometimes called agtech.

2.3.1.1 Robots

Self-steering tractors have existed for some time now, as John Deere equipment works like a plane on autopilot. The tractor does most of the work, with the farmer stepping in for emergencies. Technology is advancing towards driverless machinery programmed by GPS to spread fertilizer or plow land. Other innovations include a solar powered machine that identifies weeds and precisely kills them with a dose of herbicide or lasers. Agricultural robots, also known as AgBots, already exist, but advanced harvesting robots are being developed to identify ripe fruits, adjust to their shape and size, and carefully pluck them from branches.

2.3.1.2 Drones and satellite imagery

Drone and satellite technology are used in precision farming. This often occurs when drones take high quality images while satellites capture the bigger picture. Light aircraft pilots can combine aerial photography with data from satellite records to predict future yields based on the current level of field biomass. Aggregated images can create contour maps to track where water flows, determine variable-rate seeding, and create yield maps of areas that were more or less productive.

2.3.1.3 The Internet of things

The Internet of things is the network of physical objects outfitted with electronics that enable data collection and aggregation. IoT comes into play with the development of sensors and farm-management software. For example, farmers can spectroscopically measure nitrogen, phosphorus, and potassium in liquid manure, which is notoriously inconsistent. They can then scan the ground to see where cows have already urinated and apply fertilizer to only the spots that need it. This cuts fertilizer use by up to 30%. Moisture sensors in the soil determine the best times to remotely water plants. The irrigation systems can be programmed to switch which side of tree trunk they water based on the plant's need and rainfall.

Innovations are not just limited to plants—they can be used for the welfare of animals. Cattle can be outfitted with internal sensors to keep track of stomach acidity and digestive problems. External sensors track movement patterns to determine the cow's health and fitness, sense physical injuries, and identify the optimal times for breeding. All this data from sensors can be aggregated and analyzed to detect trends and patterns.

As another example, monitoring technology can be used to make beekeeping more efficient. Honeybees are of significant economic value and provide a vital service to agriculture by pollinating a variety of crops. Monitoring of a honeybee colony's health via wireless temperature, humidity and CO_2 sensors helps to improve the productivity of bees, and to read early warnings in the data that might threaten the very survival of an entire hive.

2.3.1.4 Smartphone Applications

Smartphone and tablet applications are becoming increasingly popular in precision agriculture. Smartphones come with many useful applications already installed, including the camera, microphone, GPS, and accelerometer. There are also applications made dedicated to various agriculture applications such as field mapping, tracking animals, obtaining weather and crop information, and more. They are easily portable, affordable, and have a high computing power.

2.3.2 Precision Agronomics

Precision agronomics is another important term related to the combining of methodology with technology. At its core, it's about providing more accurate farming techniques for planting and growing crops. Precision agronomics can involve any of the following elements:

2.3.2.1 Variable rate technology (VRT)

VRT refers to any technology that enables the variable application of inputs and allows farmers to control the amount of inputs they apply in a specific location. The basic components of this technology include a computer, software, a controller and a differential global positioning system (DGPS). There are three basic approaches to using VRT – map-based, sensor-based and manual. The adoption of variable rate technology is currently estimated at 15% in North America and is expected to continue to grow rapidly over the next five years.

2.3.2.2 GPS soil sampling

Testing a field's soil reveals available nutrients, pH level, and a range of other data that is important for making informed and profitable decisions. In essence, soil sampling allows growers to consider productivity differences within a field and formulate a plan that takes these differences into account. Collection and sampling services that are worth the effort will allow the data to be used for input for variable rate applications for optimizing seeding and fertilizer.

2.3.2.3 Computer-based applications

Computer applications can be used to create precise farm plans, field maps, crop scouting and yield maps. This, in turn, allows for the more precise application of inputs such as pesticides, herbicides, and fertilizers, thus helping to reduce expenses, produce higher yields and create a more environmentally-friendly operation. The challenge with these software systems is they sometimes deliver a narrow value that doesn't allow data to be used for making bigger farm decisions, especially with the support of an expert. Another concern with many software applications is poor user interfaces, and the inability to integrate the information they provide with other data sources to enrich and show significant value to farmers.

2.3.2.4 Remote sensing technology

Remote sensing technology has been in use in agriculture since the late 1960s. It can be an invaluable tool when it comes to monitoring and managing land, water, and other resources. It can help determine everything from what factors may be stressing a crop at a specific point in time to estimating the amount of moisture in the soil. This data enriches decision-making on the farm and can come from several sources including drones and satellites.

2.4 Comparison of related works

There are a number of projects that work on smart irrigation in agriculture (some crops) for me to improve and improve the performance of farms and simplify it, and these projects wore not all successful, there are those who failed in the process and there are Disadvantages in some projects.

For example, we will take some projects and compare them:

2.4.1 AI-Based Yield Prediction and Smart Irrigation

2.4.1.1 Remote Sensing-Based Yield Prediction

Remote sensing brings information about a field, crops, or an object without actually visiting the field. The information is captured with the help of different sensors and is made available in raw, processed, or analyzed form. It works on the principle of properties of objects. The properties may be chemical, physical, structural, energy emissions, etc. Sensors sense these properties and send to a storage system. In storage systems, the information is organized in a structured way. This information is analyzed to make decisions for deciding further actions required. Remote sensing techniques have numerous applications in agriculture viz. yield forecasting, damage identification, harvesting time prediction, irrigation estimation, and nutrient requirement prediction, etc. Figure 3 shows the process of remote sensing. It comprises of four basic steps viz. data capturing, data interpretation, information production, and decision making. [12]

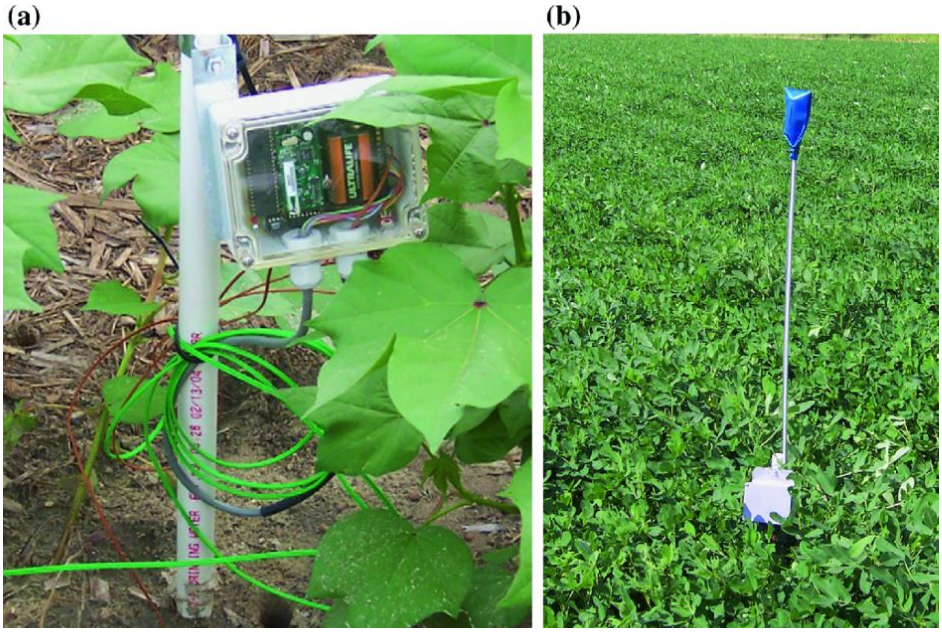


Figure 2. 3: Smart irrigation system [12]

2.4.1.2 Smart Irrigation

To cope with the shortage of water, there is a critical need for some smart irrigation systems that can irrigate more areas with low consumption of water. A comprehensive review of various techniques of smart irrigation has been presented in Jha et al. However, there is an availability of various low water consumption-based irrigation techniques, for example, sprinkler systems and drip irrigation systems; but these systems need human intervention up to a great extent. There is a scope to add features to existing systems to develop smart irrigation systems. The system continuously monitors the level of water in a crop, compares the water content available in soil and crop plant with standard need of water. It automatically starts sprinklers or drips as per water requirements of crop.presented ANN-based models for predicting soil moistures. [12]

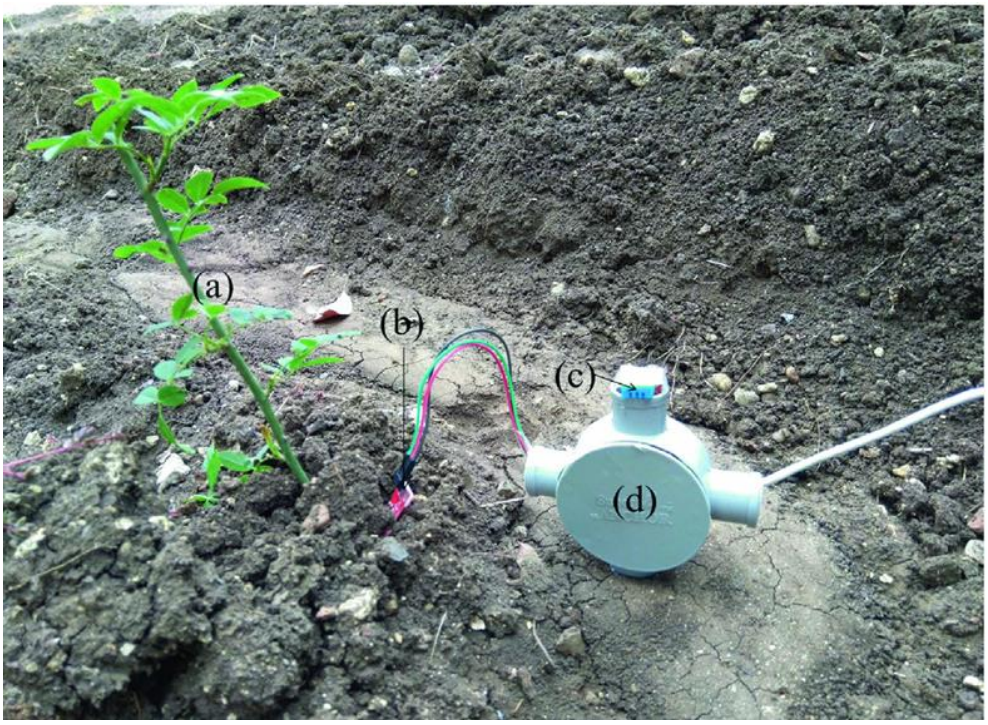


Figure 2. 4: Installation of IoT-based smart irrigation system [12]

2.4.1.3 Data Interpretation And Decision Making

After capturing the required data, the process of processing that data needs to be done in order to obtain the required information. This processing may take a while depending upon the operations/statistical techniques being applied. This process is intended also for filtering of only relevant data which needs to be considered for the next phases. Various mathematical/statistical techniques are being applied in order to get the required information. [12]

With the help of various visual representations, one can take effective decisions. The objective of these decisions is very clear: maximizing the net profit by increasing the quality as well as quantity of the crop. Also, there is a need to identify risk factors in achieving this objective.

Nowadays, the process of decision making becomes easier with the help of various AI-based techniques. Once we have obtained the required information. [12]

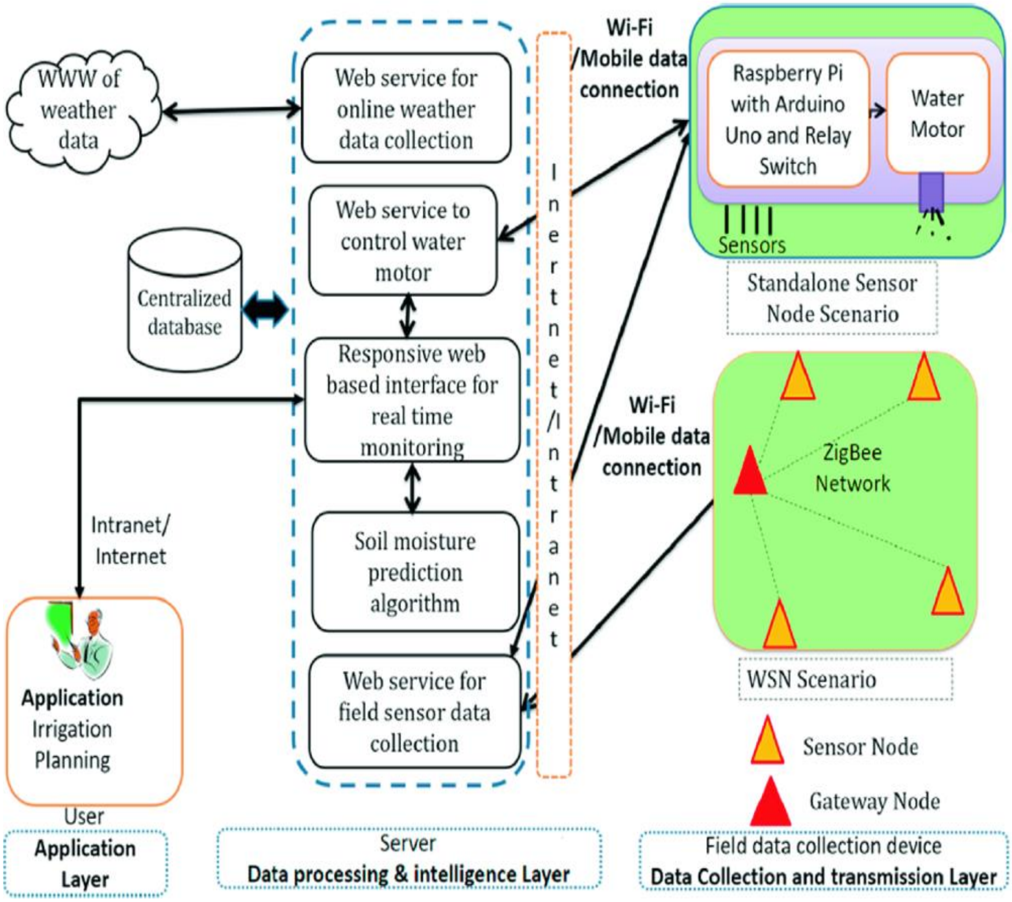


Figure 2. 5: The architecture of IoT-based smart irrigation system using open-source technologies [12]

2.4.2 Smart irrigation system using internet of things

Water sprinkler control was achieved by setting a threshold value at which irrigation should begin. When the sensors detect moisture content before the threshold, the sprinklers are switched on till the soil is completely moist. Figure 6 shows the flow chart of the system.

The information from sensors is transmitted to an online database from where it is used to display on a website. The webpage displays the moisture content in soil which has been divided into two categories : Low and High. Pump is to be switched on when the moisture content is low. The threshold values depend on the type of soil used. Readings from the two sensors were also transmitted to a THINGSPEAK channel to obtain graphs. ThingSpeak is an open data platform and API for the Internet of Things that enables you to collect, store, analyze, visualize, and act on data from sensors or actuators, such as Arduino.

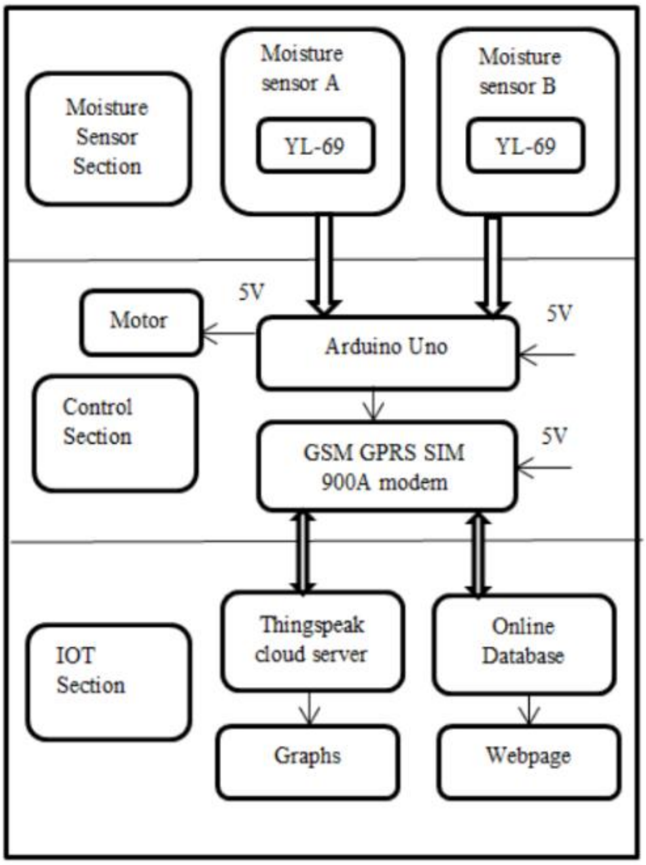


Figure 2. 6: Overall Engineering Design

2.4.3 Smart Irrigation System: A Water Management Procedure

In this project, work was done on the Internet of Things to irrigate plants using several sensors, which measure moisture in the soil, and there are sensors that measure the amount of water in the tank to give value and knowledge of the amount of water remaining in it and on the basis of which the watering process is done and used in the Arduino circuit consists of the moisture content sensor and the ultrasonic sensor as shown in Figure 7. The moisture content sensor measures the amount of water in the soil, converts this soil moisture content into electronic signal and sends the signal to the microcontroller. The ultrasonic sensor used is positioned on the reservoir. It functions as a transducer, converting water depth in the reservoir (distance of water surface from sensor) into electronic signals sent to the micro controller. It must be noted however that the electronic signals from the two sensors are analog signals.

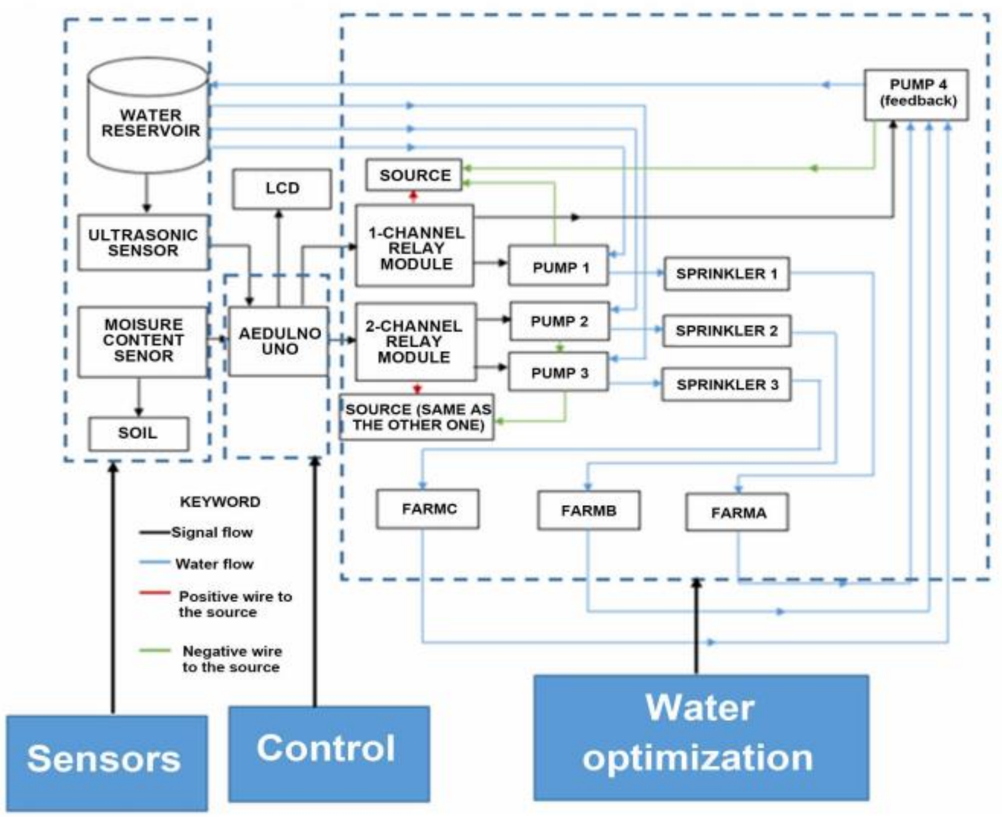


Figure 2. 7: Block diagram of the smart irrigation system [14]

2.4.4 Comparison

Table 1: Comparison table for some projects

projects	Abstract	Objectives	The material used	type of connection used	Techniques of artificial intelligence
AI-Based Yield prediction and smart irrigation	This project presents different techniques and applications of artificial intelligence for yield prediction and smart irrigation.	- Optimum utilization of water. - Providing complete irrigation data through cloud computing. - Crop control by growth or yield.	- Raspberry Pi - Arduino - Soil moisture sensor - Temperature sensor - Smart sensor array for cotton field	GSM module	Machine Learning Techniques

		- Give the farmer the time to put the fertilizer	-Modified sensor array for peanut.		
Smart irrigation system using internet of things	The project describes the smart irrigation system using the concept of IoT.	- Control water quantity - Inform the farmer of all new things on the farm - Irrigation of the crop without farm intervention	- Arduino Uno - Explore ESP8266 Wi-Fi Module - Soil Moisture Sensor - Solenoid Valve - Submersible Motor Pump - Relay Circuit.	Wi-Fi module	Rule-based reasoning
Smart irrigation system: a water management procedure	This project proposes an automated irrigation system which monitors and maintains the desired soil moisture content via automatic watering.	- Control water quantity - Soil moisture control - Watering plants without entering farms	- Arduino Uno. - Two YL-69 soil moisture sensors. - GSM-GPRS SIM900A modem. - sim with 3G data.	GSM module	ThingSpeak

After studying the related work presented, we noticed that we have an Internet of Things solution, we must first make sure of these points:

- Choose the appropriate protocol for our architecture.
- Monitor our environment and get a general idea about it in order to choose the decision that should be taken in our system.
- Gathering the necessary information that helps us to take appropriate decisions
- An in-depth field study on the environment surrounding the project
- Determine the component on which the study will be based
- Considerate the available remote stock
- Selection of specific sensors and motors.
- Information security to protect it from piracy (theft, data corruption, etc.)

The control objectives to be achieved are:

- Smart irrigation based on careful study
- Rationalize the use of water
- Work at the convenience of the farmer
- Improving product quality
- Saving energy used in traditional irrigation as and the cost
- Reducing or erasing human errors

2.5 Conclusion

When we studied some of the completed projects in this field, we noticed that there are some deficiencies in it in terms of achievement or mastery, so we thought that we should overcome all these mistakes committed and improve, develop and become familiar with all the requirements of good irrigation and free from faults and shortcomings that may make the project unable to play its role Well or disrepair.

Chapter 3

System conception

Chapter 3

System design

3.1 Introduction

Irrigation of agricultural crops is a delicate and sensitive process for plants and trees. Water is an important and necessary component to ensure that the best agricultural crops and the finest fruits are produced.

When comparing the irrigation process and its importance to trees, methods and methods used by farmers, we find that these methods are very primitive and have not been studied in many aspects. The amount of water used for irrigation has not been studied and is not scientifically based, and the methods used are very old, as well as the errors that were made during this process.

Therefore, we decided to conduct an in-depth study of the process and extract an intelligent and automatic system that performs the irrigation process in a smart way without human intervention to get rid of most of the problems arising from primitive irrigation, as well as contribute to improving the production of high-quality crops while taking into account the rationalization of water consumption.

3.2 Smart system to optimize water consumption

After the in-depth study that we conducted on the irrigation process of palm trees in the Tolga area in particular, we noticed that there are several problems centered on this topic, which make it difficult to practice for farmers, and this is what causes a decrease in the labor force and among these problems is mentioned:

Squandering water.

- Crop damage due to excessive or scarcity of water used for irrigation.
- The use of traditional methods and their indiscriminate use that is not based on a detailed study.
- Fatigue due to the long time and inappropriate.

- The element of human error, for example forgetting to turn off the valve after irrigation is complete.
- That is why we decided to develop a program that carries out the irrigation process in an intelligent and autonomous way that helps the farmer improve his agricultural life and saves him from hard work

This program calculates the amount of water the palm tree needs, taking into account the changes in the weather, such as temperature and humidity, which are essential factors in the irrigation process.

Evaporation plays an important role and must be taken into consideration as well.

3.2.1 General Architecture

The image below represents a preliminary scheme of our proposed system, where we have installed a smart system that brings information from the various sensors and sends it to the cloud, and these sensors are installed in a thoughtful way on the farm to extract all the information we need in the process of data processing and the customer can obtain all the necessary information about The field from application web connected with cloud.

And the smart irrigation system controls the pump, so it determines the amount of water, the duration of operation, as well as the appropriate time for operation.

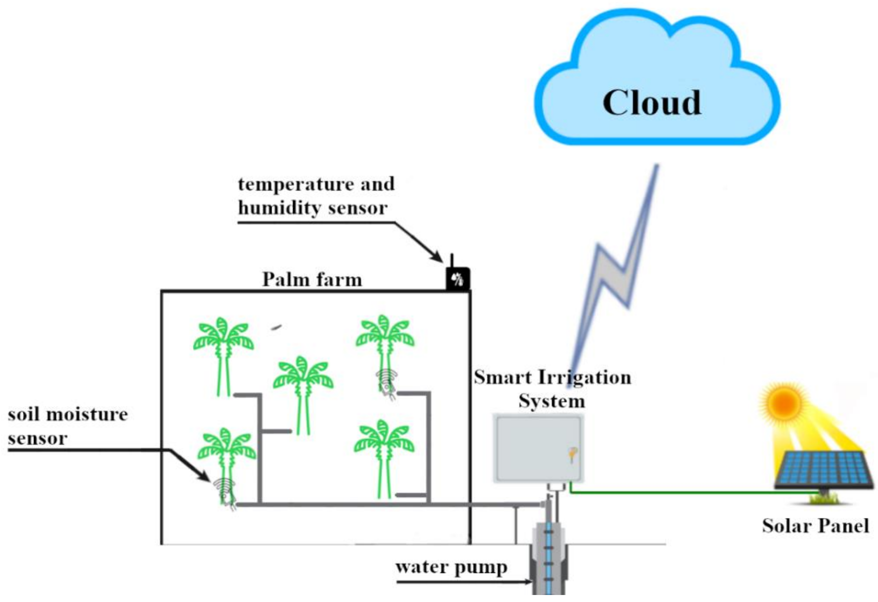


Figure 3. 1: General Architecture

3.2.2 Detailed architecture

The detailed architecture is presented in Figure 3.2 below. Soil moisture sensors have been installed, as well as a temperature and air humidity sensor on the farm well and thoughtfully to extract accurate and non-confused information. Each sensor has been carefully placed and is linked to a system that controls it when the data is needed is linked to the gateway system. Which sends the information to the cloud (decision make system) for storage, processing and sending it to the web server to be redirected to the client and there is a control system in the pump when needed to be at the field level to control the pump closely.

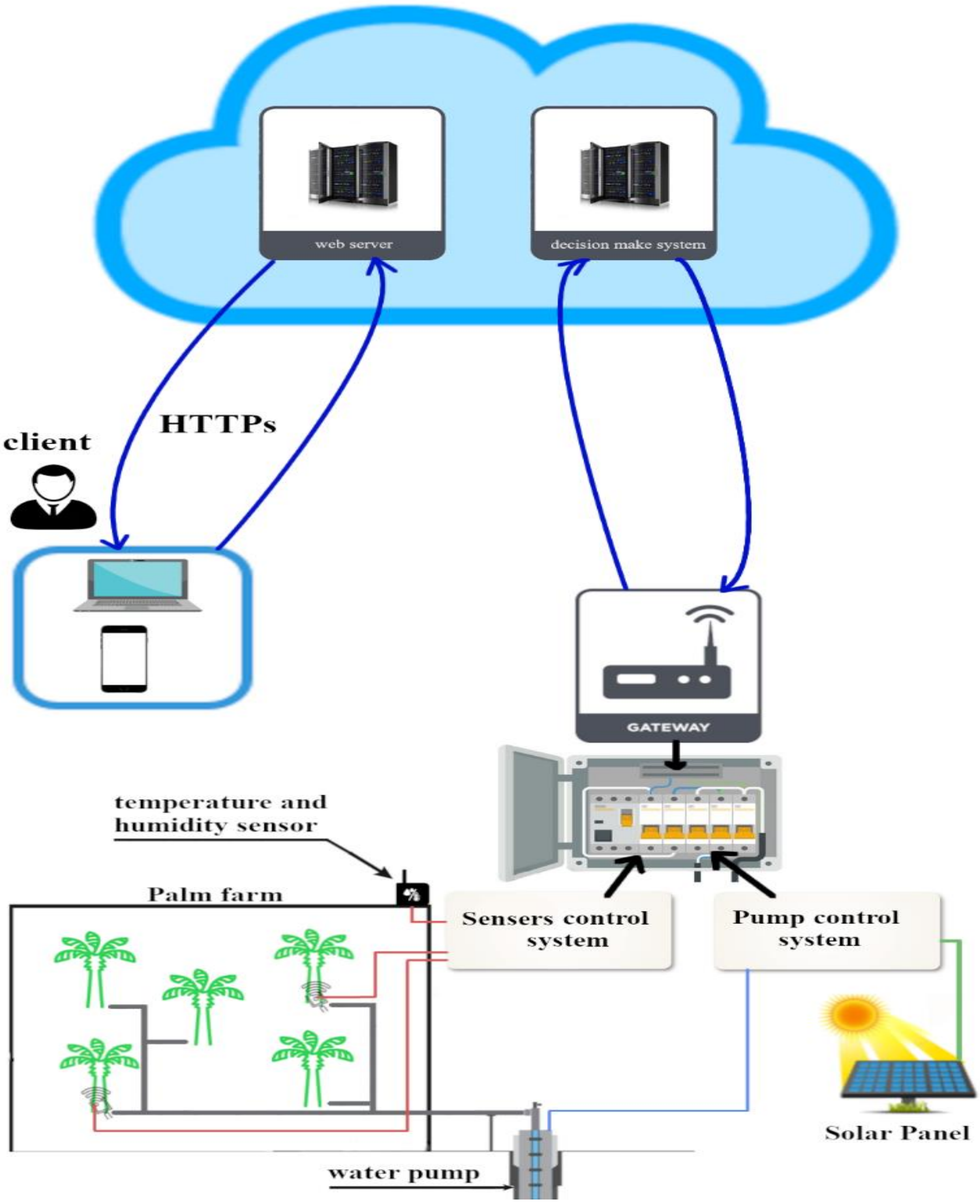


Figure 3. 2: Detailed architecture

3.2.2.1 Deployment and functionality

- The sensors on the farm should be placed neatly, the soil moisture sensors as well as the temperature and humidity sensor that should be in the middle of the farm.
- The sensor control system must be placed in the appropriate place to be able to access all the sensors without exception, as they are connected to them wirelessly.
- The gateway (3G / 4G…) should be accessible by the system to cloud.
- As for the pump, it must be located in a place that covers the farm, so the water should reach all the palms.
- Power source: using a solar panel would be a good choice in a wealthy region in solar energy.

3.2.2.2 Smart Irrigation System (Farm Side)

This system is installed at the field level because it is the main responsible for the sensors, the pump and the power source.

1. **Sensors control system**

   The system in our hands collects information from the sensors implanted in the field to feed us with the data necessary for the course of events in the field, and then we send it to the gateway, which in turn redirects it to the cloud for filtering, processing, storing and automatically taking the optimized decision.

2. **Gateway**

   It is a system that allows us to send the data obtained from the sensors through the sensor control system, and we send it to the cloud, as it acts as a link between the farm and the cloud.

3. **Pump control system**

   To control the pump in an intelligent and automatic manner. When the data arrives from the Decision make System, it analyzes it using our developed artificial intelligence based and then decides whether the farm needs irrigation or not.

   And it determines the amount of water needed and the time that the irrigation process will take and until the appropriate time for the process. We will use renewable energies represented in solar energy, and this is why our system makes the irrigation process during the daytime (during the presence of the sun) to reduce energy consumption, the algorithm 1 explains how the pump control system works.

```
IF the farm needs irrigation:
    Calculate the amount of water needed ();
    Time calculation taken ();
    IF the time is right for irrigation:
        The pump is working ();
        Send notification to client ();
    ELSE
        IF the sunrise is near:
            We wait until the sun rises ();
        ELSE IF the battery is sufficient:
                The pump is working ();
        ELSE
            We wait until the sun rises ();
            Send a low battery notification ();
        END
    END
END
```

Algorithm 1: Pump operation algorithm

3.2.2.3 Cloud Side

1. Web server

This server allows the client to access to the web portal which present a dashboard to know all the information about the farm like temperature and humidity, whether the farm is in the irrigation stage or not, and all the statistics that the system made in the form of graphical curves and others.

2. Decision make system

It analyzes the data coming from the sensors and then studies it and arranges it in the database and then analyzes it through artificial intelligence methods to see if the farm needs irrigation or not.

If it needs to, it sends the data to the pump control system to perform the operations necessary to deduce the amount of water and the time required for the process and the appropriate time for it.

3.3 Data and its handling process

In our study of this project, we rely on artificial intelligence to help us make the right decision if the farm needs irrigation and how much water is for this complex process, and this we will use the artificial neural network model to determine these results.

The feedforward neural network ,In this network, the information moves in only one direction forward from the input nodes, through the hidden nodes (if any) and to the output nodes. There are no cycles or loops in the networkIt has many uses such as completing writing, translating and converting sounds into texts.

3.3.1 Data used

Table 1 represents the different metrics used in our system

Objectives	Data (Input)	Actuators	Resources	Output
Rationalize the use of water and energy	✓ SM: soil moisture ✓ T: temperature ✓ KC: coefficient ✓ ET: evapotranspiration	✓ water pump ✓ solar panels	✓ clean energy ✓ water	✓ the amount of water ✓ The required time

Table 2: Parameters and components projects.

- **Soil moisture:** We determine the suitable soil moisture for the palms. If this value is reduced to a minimum, we analyze the necessary data, and then we perform the irrigation process.

Age palm	Soil moisture %	Actions
Palm cuttings (1-6 years)	5% – 10 %	Check condition of irrigation conditions
	11% - 100 %	There is no need for irrigation
Adult palm	0% - 3 %	Check condition of irrigation conditions
	4% - 100%	There is no need for irrigation

Table 3: The percentage of soil moisture needed for irrig

- **Temperature** plays the main factor in the growth of palm trees and giving us high-quality fruits, their irrigation depends on the temperature of the surrounding atmosphere, The temperature of (32-38 C°) is the ideal temperature for the growth of this tree, and it can withstand high temperatures up to (49 C°) and lows up to (-12 C°), but the most of the leaves fall out. [17]
- **KC:** It is a coefficient that is calculated by specialists in agriculture, and each plant has a special coefficient and helps to calculate the amount of water the tree needs at each stage of its life and as well as each period of time in one year.

$$KC = (Kcb * KS) + Ke$$

With: Kcb: Basic crop coefficient when water is not a limiting factor for the development of the plant (Doorenbos & Pruitt. 1977). For our region we have a Kcb of 0.8 (Awadiss et al ... 2005). KS: Factor linked to the availability of water in the soil. It is varied by [0-1]. Ke: Coefficient of water evaporation. Ke is equal to 0.3 (Awadiss et al ... 2005). [20]

months	December, January, February	March, April	May, June, July, August	September, October, November
Palm cuttings (1-6 years)	KC = 0.1 * Age	KC = 0.1 * Age	KC = 0.2 * Age	KC = 0.2 * Age
Adult palm	KC = 0.7	KC = 0.9	KC = 0.95	KC = 0.8

Table 4: The coefficient Kc of palms.

- **Evapotranspiration:** It is the evaporation that occurs to the plant and changes according to the temperature. The higher it is, the greater the evaporation rate, and vice versa, and it has an important effect in calculating the amount of water needed for the palm.[18]

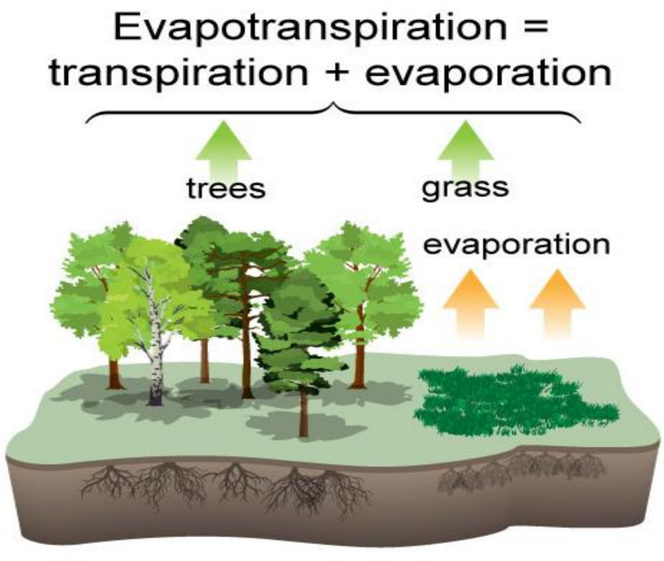


Figure 3. 3: illustration of evapotranspiration [19]

Evapotranspiration (ET)

The emission of water vapor or evapotranspiration, results from two phenomena: evaporation, which is a purely physical phenomenon, and the transpiration of plants. The recharge of the water table by precipitation falling during the period of vegetation cover can be limited. In fact, most of the water is evapotranspired by vegetation. It encompasses the loss of water due to the climate, losses from evaporation from the soil and transpiration from plants. [18]

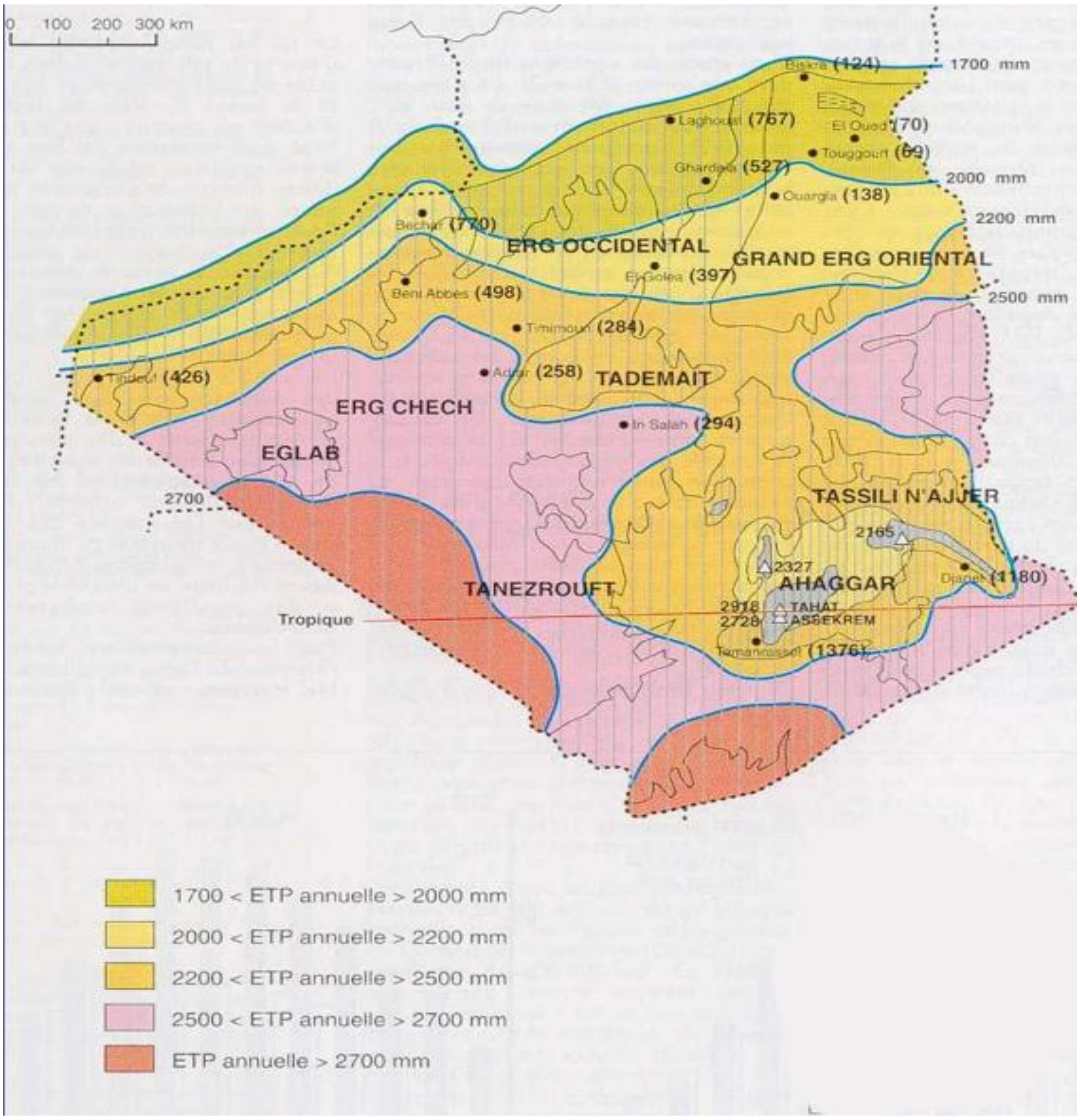


Figure 3. 4: Reference evapotranspiration from 1700 to 2700 mm / year, in Algeria [17]

Calculation equation evapotranspiration:

$$\mathbf{ET} = \frac{\Delta\, Rn \; + \; \gamma\, Ea}{\Delta + \gamma} \quad [17]$$

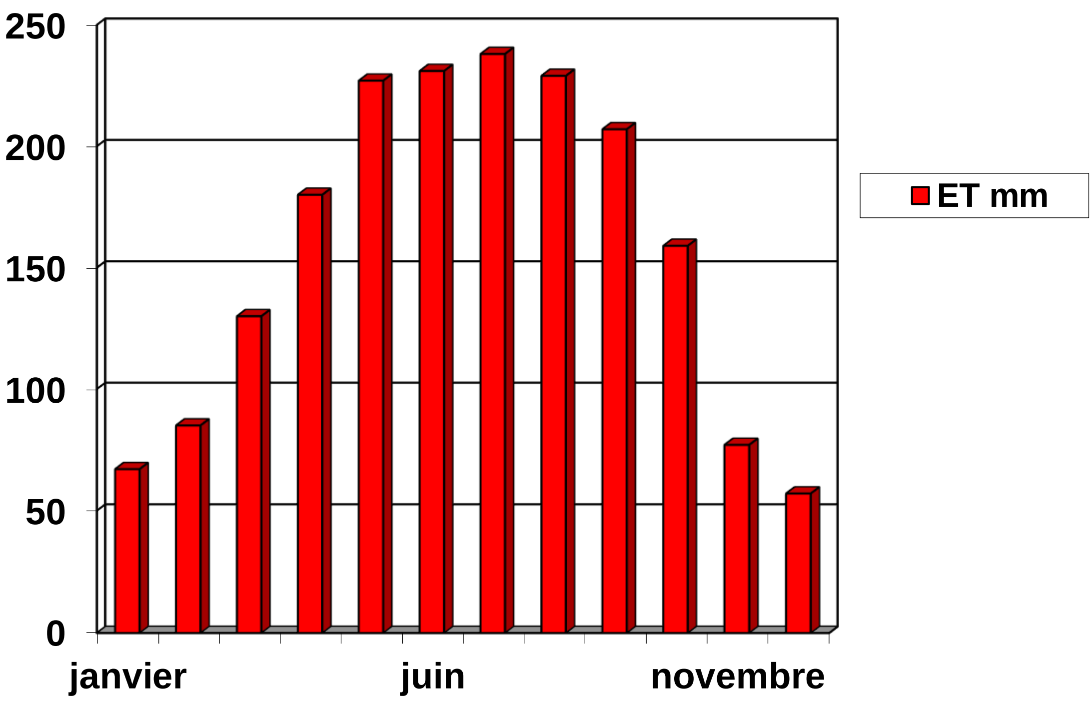
Rn = net radiation.

Ea = evaporating power of the air (wind humidity).

Δ = slope of the water vapor pressure curve.

γ = psychometric constant.

Figure 3. 5: monthly evapotranspiration in Biskra [17]



3.3.2 Dealing with data

The decision-making system works to know if the farm needs irrigation at this time or not, and for this it analyzes the data coming from the farm and decides if it is compatible or there is fluctuation in the information. A chart of analysis of this data is attached below:

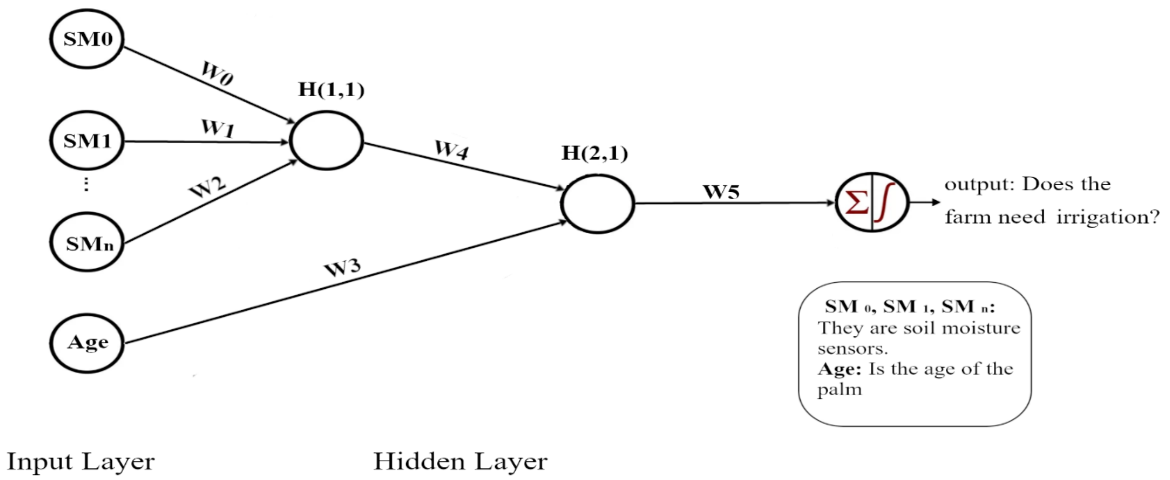


Figure 3. 6: The ANN[1] model in decision making system.

$$\text{Output} = \begin{cases} 1 & \textit{the farm need water.} \\ 0 & \textit{The farm doesn't need.} \end{cases}$$

The system collects data from the sensors and then applies the comparison process to it, which is the calculation of the Midrange, and then we combine it with the smallest value and reduce it from the largest value, and we compare the two results. If they are close, the results of the sensors are ideal, and if they are far apart, there is a defect in the data.

In this case, the system sends a notification to customers that there is a problem with the data imported from the sensors.

If the data is perfect, in this case, he compares the moisture content of the soil and the age of the palm and decides if it needs irrigation or not.

If we assume that there are 5 sensors in the farm and give us the following data:

Sensors	Values	Status
Sensor 0	5%	
Sensor 1	10%	max
Sensor 2	7%	

Table 5: experimental values for the sensors.

[1] artificial neural network

Sensor 3	2%	
Sensor 4	1%	min

Midrange = $\frac{\max + min}{2} = \frac{10+1}{5} = 5.5$

X = min + midrange = 1 + 5.5 = 6.5

Y = max + midrange = 10 - 5.5 = 4.5

Note here that the value of (x= 6.5) and the (mid-range= 5.5) value are converging, and so is the value of (Y= 4.5). In this case, values are accepted because they are close and ideal. If they are not, then the values will be considered illogical and the system notifies the customer.

Since the results are correct, we calculate the arithmetic mean and compare it with the age of the palm. If the age matches the humidity rate in the farm when the system sends a notification to the pump control system with some data for the system to play its role.

Arithmetic mean (SMA) = $\frac{5+10+7+2+1}{5} = \frac{25}{5} = 5$

IF the palm is adult: // >6years

IF 0 < = Arithmetic mean (SMA) < = 3:

Send the notification to the pump control system ();

END

ELSE // Palm cuttings (1-6 years)

IF 5 < = Arithmetic mean (SMA) < = 10:

Send the notification to the pump control system ();

END

END

Algorithm 2: Determines if the farm needs irrigation

When the notification arrives from the decision-making system, the farm's need for irrigation, it performs calculations to find out the necessary amount of water.

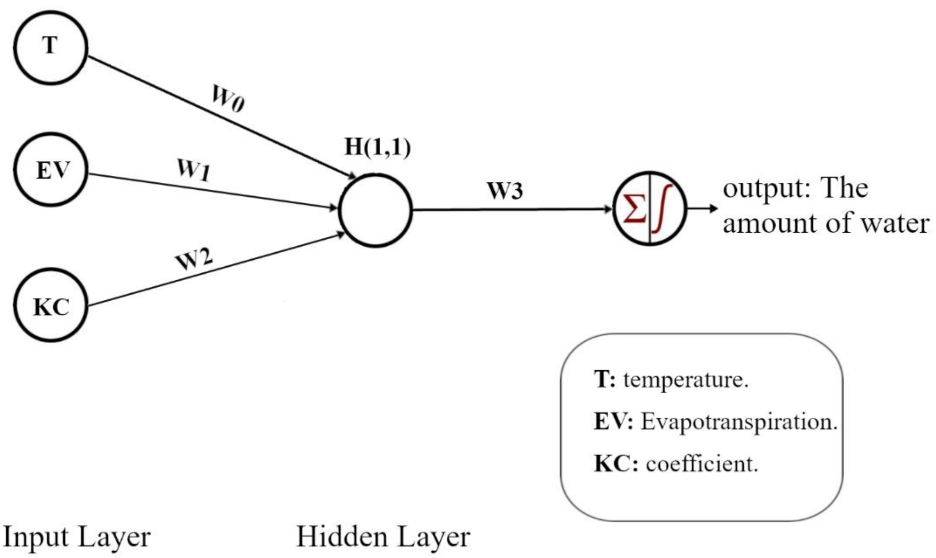


Figure 3. 7: The ANN[2] model in Pump control system.

The pump control system performs an important process which is analyzing the data received from the control system and calculating the amount of water needed for irrigation, which is considered an essential process.

After the arrival of a warning about the necessity of irrigation, the system arranges the incoming information and calculates the amount of Evapotranspiration, using the international meteorological site to find out the level of Evapotranspiration at that particular time.

The percentage of Evapotranspiration helps us to know the amount of water, the Tempreture and the coefficient KC. These data are collected and processed by the system, and in the end the amount of water required for the irrigation process is derived.

Use the site[3] to find out the Evapotranspiration level in the farm by locating the farm location, which is fairly accurate compared to some other sites.

[2] artificial neural network
[3] https://www.weatherbit.io/

The information provided by this site is mostly free, but you must register in it and then provide you with an API KEY to be able to use it and it has a specific time and it is a month after the expiration of the period this KEY is not valid again.

```
IF the palm is adult: // >6years
|    KC = Get_kc_this_month ();
|    EV = Get_evapotranspiration_this_day ();
|    Amount_of_water = [(KC * EV * 10) * 1000] / 160;
ELSE // Palm cuttings (1-6 years)
|    list_1 = [12, 1, 2, 3, 4];
|    list_2 = [5, 6, 7, 8, 9, 10, 11];
|    IF the month is in list_1:
|    |    KC = 0.1*Age;
|    ELSE // the month is in list_2
|    |    KC = 0.2*Age;
|    END
|    EV = Get_evapotranspiration_this_day ();
|    Amount_of_water = [(KC * EV * 10) * 1000] / 160;
END
```

Algorithm 3: The amount of water needed for irrigation

Amount_of_water (Liter) = [(KC * EV * 10) * 1000] / 160; [17]

We have multiplied by the number 1000 to convert the value into cubic meters (m^3). As for the division by 160, because the value was per hectare and a hectare contains 160 palm trees, and when dividing by 160 we get the amount of water for each palm tree in liters. [17]

Irrigation systems used:

We will use an economical and thoughtful irrigation system to save energy and ensure that water is not wasted.

Figure 3. 8: system ajutage with a calibrated opening.

These calibrated nozzles offer a range of flow rates ranging from 200 L/ h which is significantly greater than the drip. They allow in particular: [23]

- Significant soil moistening, and therefore optimum recovery of the plantings carried out in the dry period.
- Immediate reconstitution of the wet bulb (volume of moistened soil) in the event of prolonged interruption of irrigations.
- Possibility of leaching salty soils without resorting to other means.

The time required for irrigation:

Time_required_for_irrigation (h) = Amount_of_water / 200;

We divided by 100 because the water pumping rate is 200 liters per hour and this is to find out how many hours the irrigation process will take. [23]

3.4 Web Portal

This web portal will be a link between the customer and all the information about the farm that is in the cloud, and each customer has an account and the supervisor.

- **The home page:** it is the first page that pops up when you open the web application, in which you will find a brief explanation about the system, and from there you go to the login page.
- **The login page:** this page allows the user, whether a customer or a supervisor, to enter the email and password, and their validity is verified to add security to the application.
- **Monitoring page:** this page allows the customer to monitor everything that happens on his farm in terms of temperature, humidity, and battery condition, and displays a chart for the latest developments.
- **The irrigation page:** it is a page to see if the farm is in the irrigation stage, the last time it was irrigated, and all the information and conditions that allowed for this process.
- **The statistics page:** on this page, all irrigation operations performed by the system are displayed and analyzes are also presented in the form of a graph.
- **History page:** on this page, the data on which the system depends is displayed for decision-making.
- **Farm information:** All information about the farm is displayed and fixed, such as the number of palms, age of palms, geographical location and the area used.
- **Client profile:** Here the customer finds all the general information about him and can change it to what suits him.

3.4.1 Use case diagram

The use case diagram is a graphical representation that is used to give a holistic view of the functional behavior of a system. It describes the interaction between the actor and the system. To do this we must identify the use cases made by the users (the customer and the admin), as illustrated in figure 3.9 on the next page

Operations performed by users

1. **By the customer**

- **Visit the home page:** here the customer can communicate with the supervisor as well as know everything related to automatic smart irrigation, and from here he moves to enter to know the latest developments in the farm.
- **Authentication:** At this phase, the customer enters the email and password to enter the application.
- **Visit the monitoring page:** the customer will be able to know all the developments of the farm in terms of temperature, humidity, the amount of the battery, and if the farm is in the process of irrigation.
- **Visit the irrigation page:** the customer will be able to know everything related to the irrigation process on the farm and monitor it step by step, and all the information from the amount of water and the time required to complete the process.
- **Visit statistics page:** The client can know all the analysis done by the system.
- **Visit history page:** here the customer will find the irrigation operations carried out by the system in the form of graphic curves and everything related to this process.
- **Farm information:** In it, the client will find all the information about his own farm (location, number of palm trees, age of palm trees, etc. …).
- **Client profile:** The customer finds all the personal information about him and can change it.

2. **By the admin**

- **Consult the home page:** from this page the admin can access his account in order to have access to its features.
- **Add, edit and delete a customer:** view the customer list save and enter all the information required for a new account for a new customer.
- **Add, edit and delete a farm:** view the farm list save and enter all the information required for a new farm from a new customer.
- **Information:** Everything related to the messages and notifications you receive from clients or others.

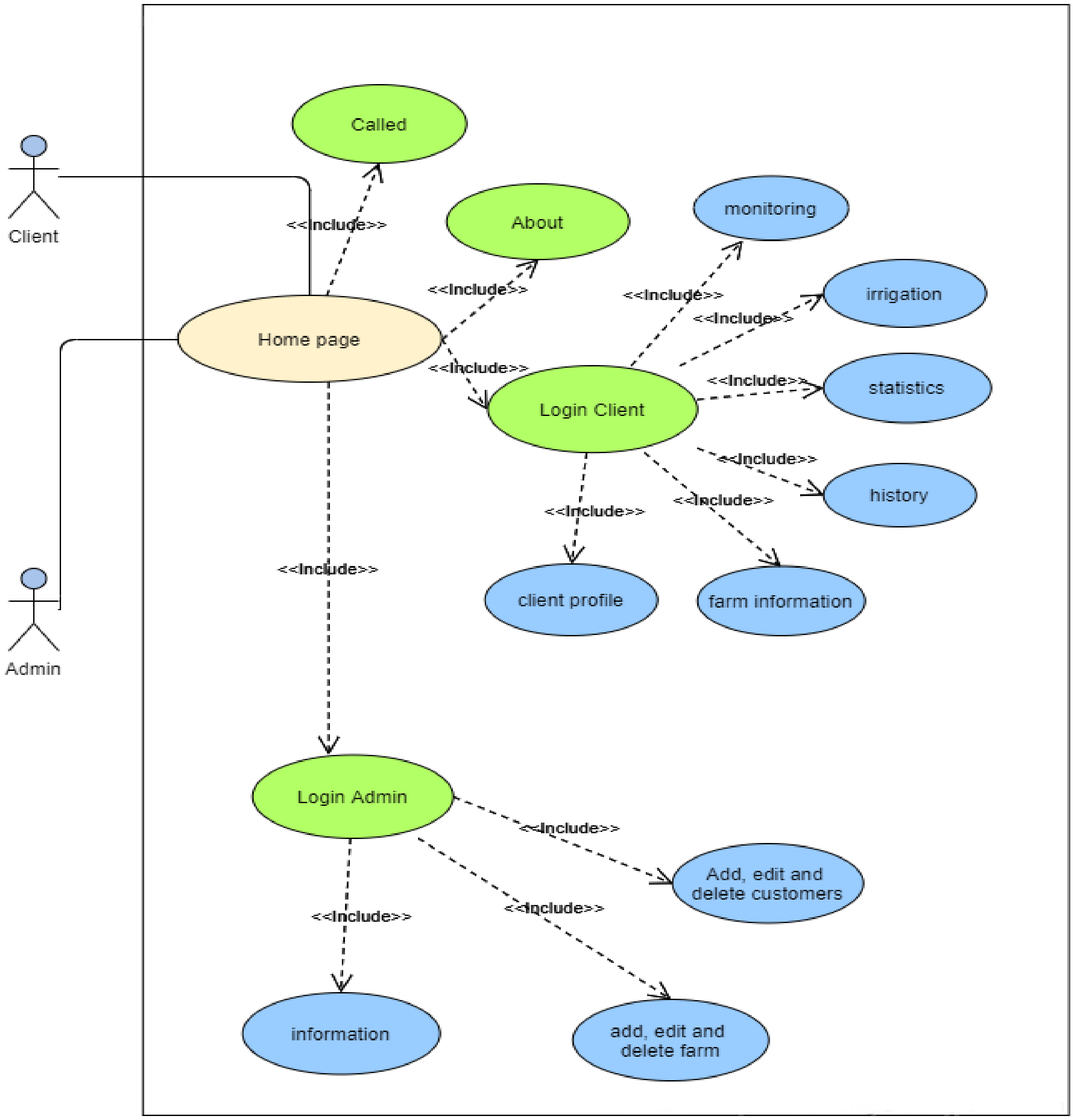


Figure 3. 9: Use case diagram.

3.4.2 Sequence diagram

3.4.2.1 Sequence diagram of the "Information collection"

Figure 3.10 represents the schematic diagram of collecting data from the farm that is collected from the wireless sensors distributed in the farm and then we send it to the sensor control system, which in turn sends it to the decision-making system and stores it in the data server.

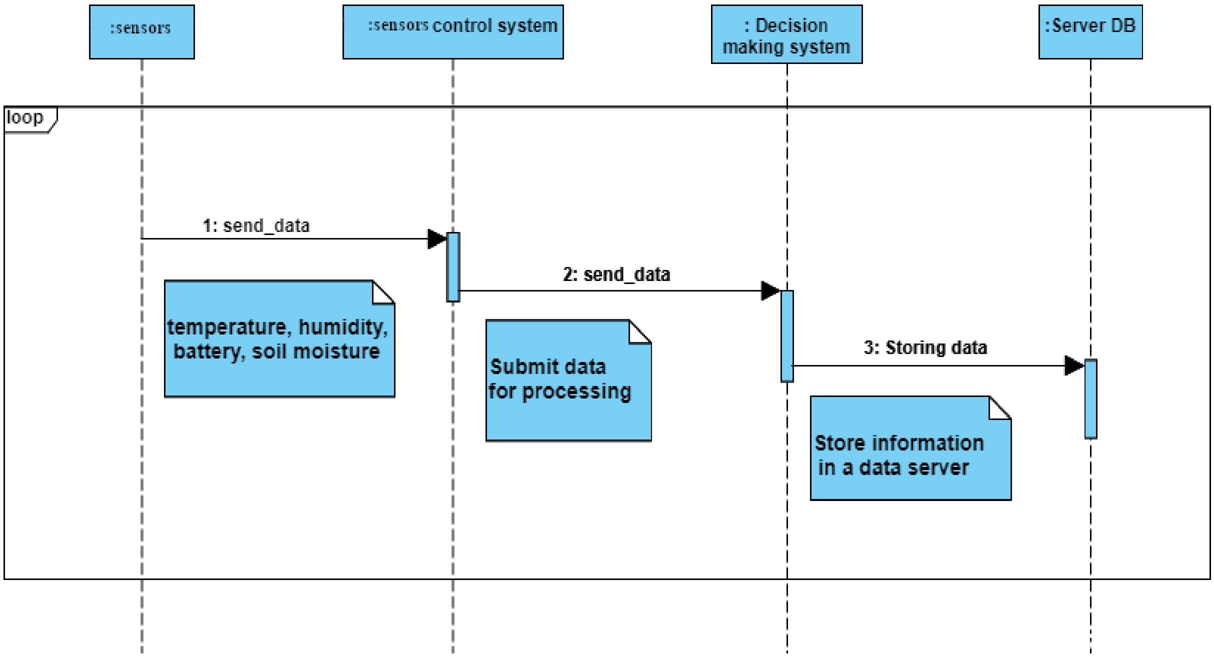


Figure 3. 10: Sequence diagram of Information collection.

3.4.2.2 Sequence diagram of "Decision making system"

It performs the calculation process and concludes if the farm needs irrigation. When needed, a notification is sent to the pump control system to operate it, after analyzing the sent data.

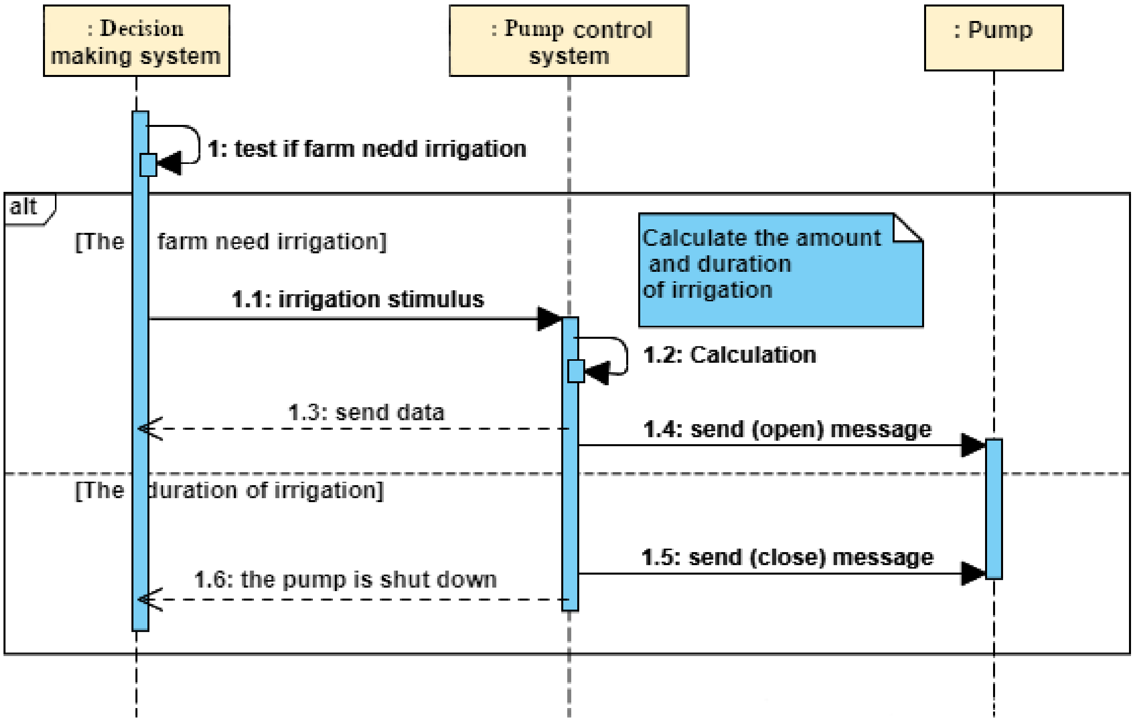


Figure 3. 11: Sequence diagram of Decision making system.

3.4.2.3 Conceptual model of our main database

- A customer can have one or more farms.
- The farm can be divided into several parts and control each part separately.
- The farm contains several equipment, which are soil moisture sensors and the temperature and humidity sensor on the farm.

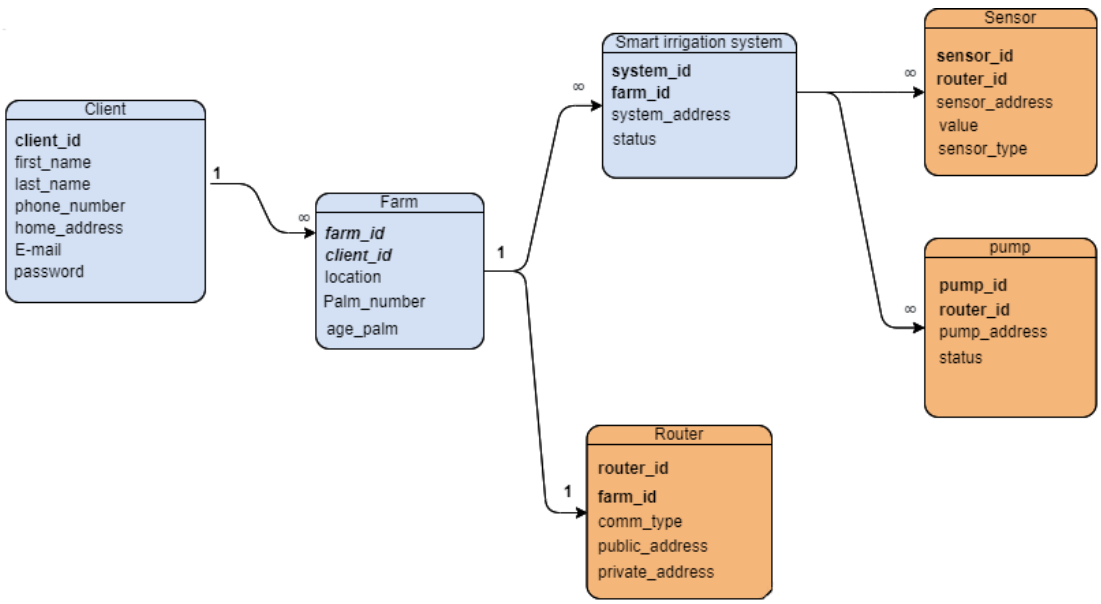


Figure 3. 12: conceptual model of our main database.

3.5 Conclusion

In this chapter we have proposed a solution to irrigate farms in an intelligent and automatic way, based on Cloud computing and Internet of Things technologies. Our system irrigates automatically and smartly farms with a large number of palms using a developed irrigation decision making system based on Artificial Intelligence technics. Which can save water and energy.

Chapter 4

System implementation

Chapter 4
System implementation

4.1 Introduction

In this chapter, we will present the implementation details of our proposed system, which is represented by the smart system deployed at the farm level according to our proposed architecture design, also the web portal developped. Finally, we illustrate and discuss the obtained results.

4.2 Programming language (python)

4.2.1 What is Python?

Python is a general-purpose coding language, which means that, unlike HTML, CSS, and JavaScript, it can used for other types of programming and software development besides web development.

That includes back end development, software development, data science and writing system scripts among other things. [23]

What is Python used for?

1. **General web development / building web apps**

Python is one of the simplest programming languages, and we mean that in a good way.

According to this great Medium article, "Python, unlike other programming languages, emphasizes code readability, and allows you to use English keywords instead of punctuation…The readable and clean code base will help you to maintain and update the software without putting extra time and effort." [23]

2. **Scientific computing data science**

Python is also used for scientific research and computing and even has several science-friendly or science-specific libraries including:

- Astropy for astronomy

- Biopython for biology and bioinformatics
- Graph-tool for statistical analysis of graphs
- Psychopy for neuroscience and experimental psychology.

Moreover, lots more. Python's role in parsing data is definitely one great advantage of learning it. Thanks to the undeniable rise of data science, chances are that more and more tech roles will revolve around it—and you will already have one of the leading languages in your toolkit. [23]

3. Machine learning

Technically, machine learning falls under data science (#2 on our list), but bear with me here. Using Python for machine learning is cool, so it felt like it warranted an additional line item.

Machine learning includes things like speech recognition, financial services.

Python is used for machine learning via specific machine learning libraries and frameworks including scikit-learn and TensorFlow. [23]

4.2.2 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. [24]

4.3 Development tools

4.3.1 PyCharm

Available as a cross-platform application, PyCharm is compatible with Linux, macOS, and Windows platforms. Sitting gracefully among the best Python IDEs, PyCharm provides support for both Python 2 (2.7) and Python 3 (3.5 and above) versions. [25]

PyCharm comes with a plethora of modules, packages, and tools to hasten Python development while cutting-down the effort required doing the same largely, simultaneously. Further, PyCharm can be customized as per the development requirements, and personal preferences call for. It was released to the public for the very first time back in February of 2010. In addition to offering code analysis, PyCharm features: [25]

- A graphical debugger
- An integrated unit tester
- Integration support for version control systems (VCSs)
- Support for data science with Anaconda

4.3.2 IBM SPSS statistics

The IBM SPSS software platform offers advanced statistical analysis, a vast library of machine learning algorithms, text analysis, open source extensibility, integration with big data and seamless deployment into applications.

4.4 Web application

This application allows the customer to know all the developments of his farm, including temperature, humidity, and the smart irrigation system for his farm.

4.4.1 Home page

When entering the application by the customer or the supervisor will meet him with this page, as it contains a simple explanation of the application and from which he can log in and he is able to know about the application or also the customer can communicate with the supervisor.

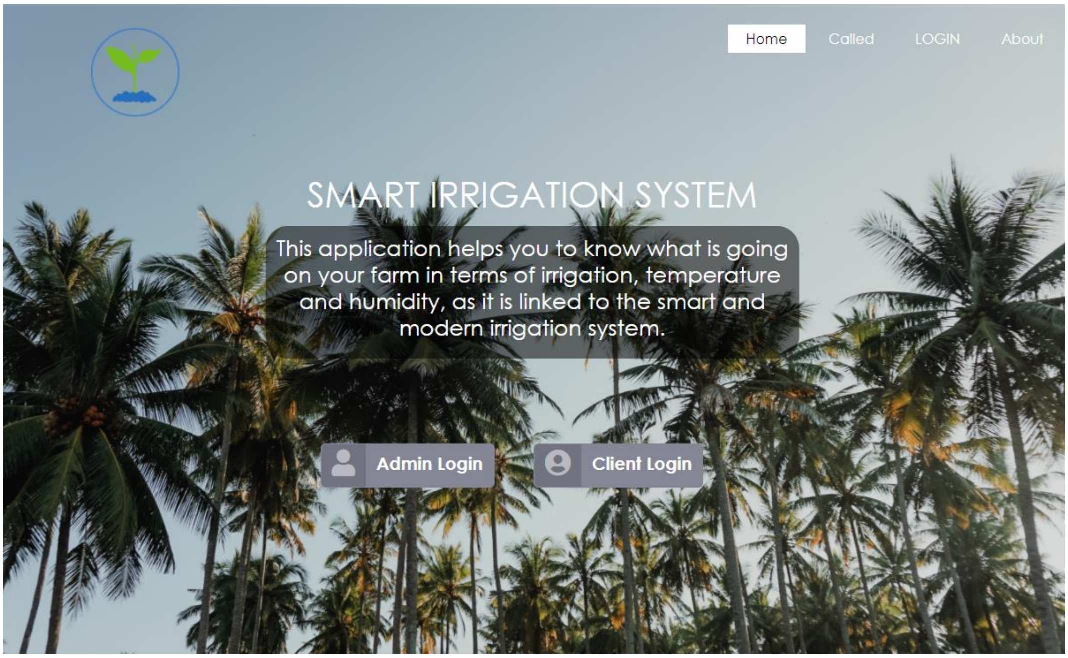


Figure 4. 1: Home page

The customer can access the page after logging in, and all the information about his farm will be shown, like temperature, humidity, battery condition, are and whether or not the farm is in an irrigated state.

It will also show him a graphical curve in which the values of the temperature, humidity and battery condition throughout the day.

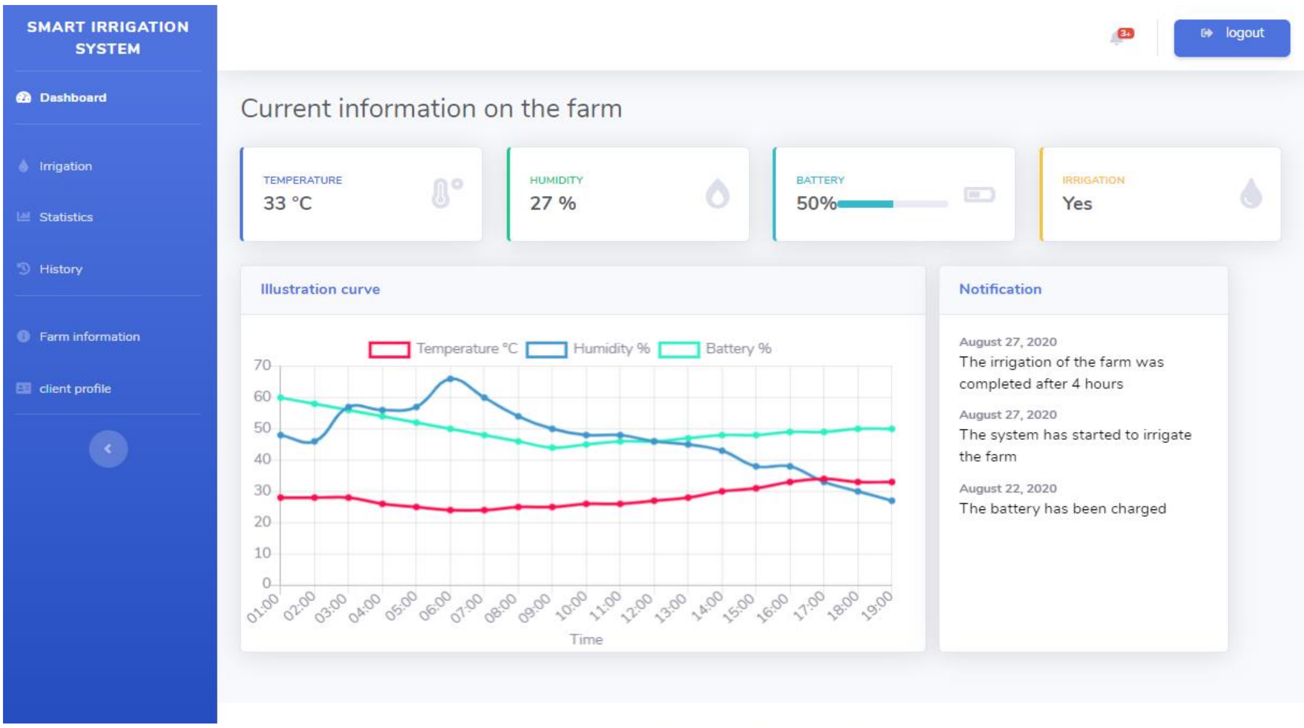


Figure 4. 2: Monitoring page

4.4.2 Automated irrigation

On this page the application shows us the state of irrigation on the farm, i.e. the latest irrigation carried out by the system of the amount of water estimated for each palm and for the farm as a whole, the time elapsed, the time of operation of the pump, the time of operation of the pump, the time of shutdown, the weather, the evaporation rate, the erosion and the amount of KC at the calculation.

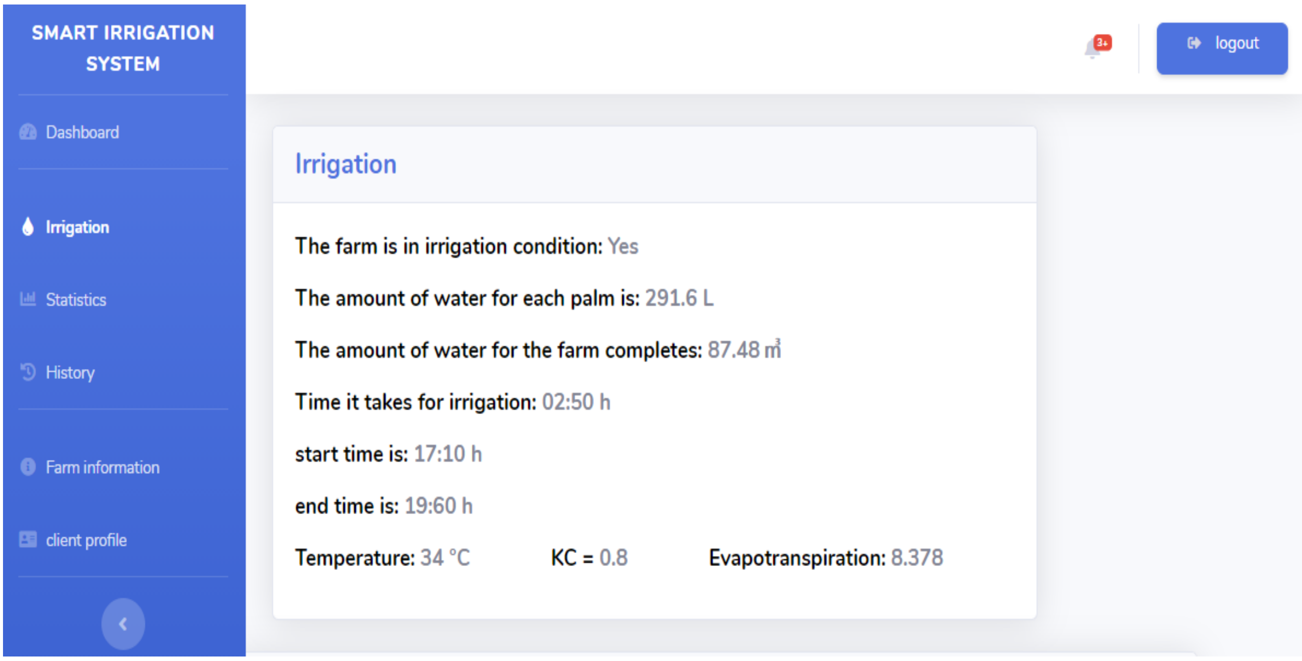


Figure 4. 3: Irrigation process information

There is a graph showing the data that the decision-making system makes compared to the data you get from the farm.

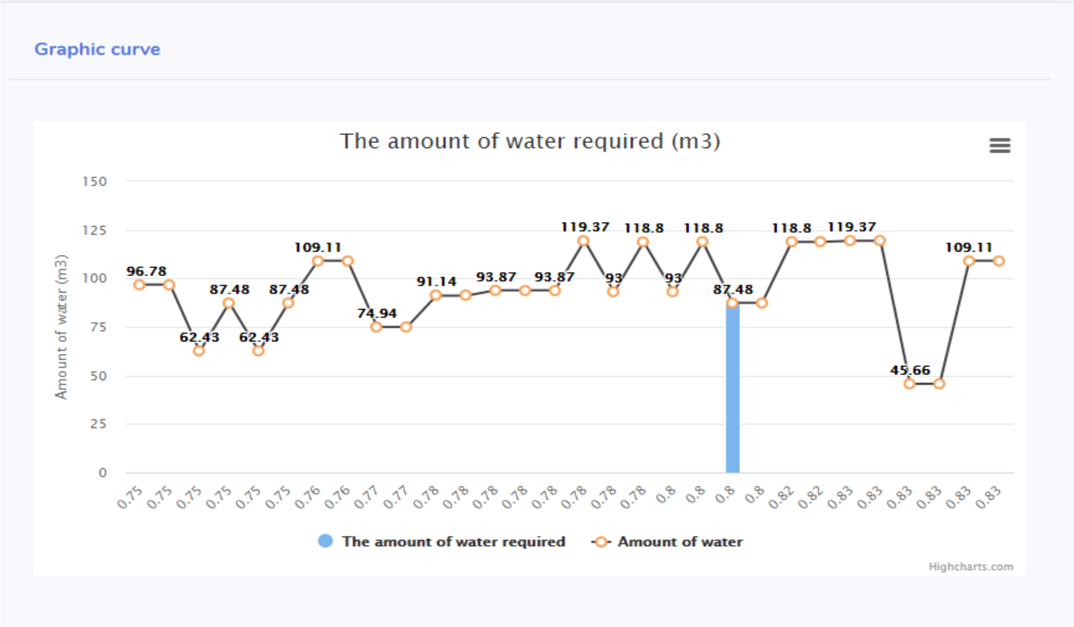


Figure 4. 4: Statistics data curve

4.4.3 Statistics

The statistics page shows the customer all the data that the system inferred and knows how to make the irrigation decision in the form of graphical curves.

The first curve is the amount of water (liters) per palm in terms of KC.

As for the second curve, it is the amount of water for each palm in terms of temperature.

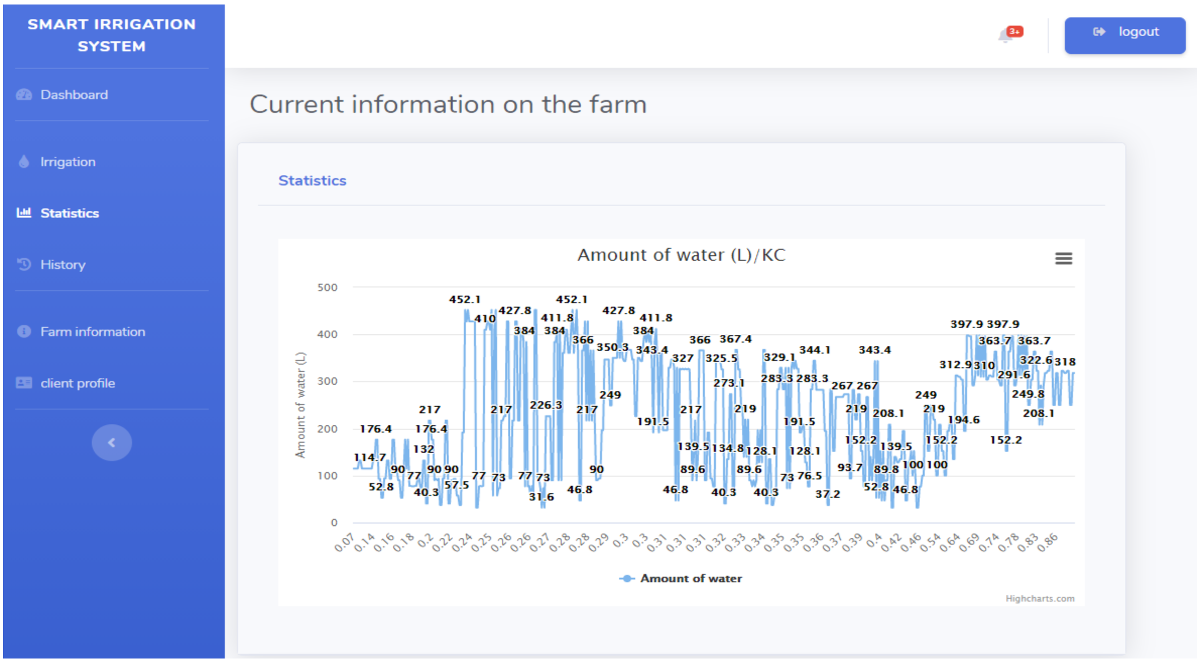


Figure 4. 5: curve of the amount of water (liters) per palm in terms of KC

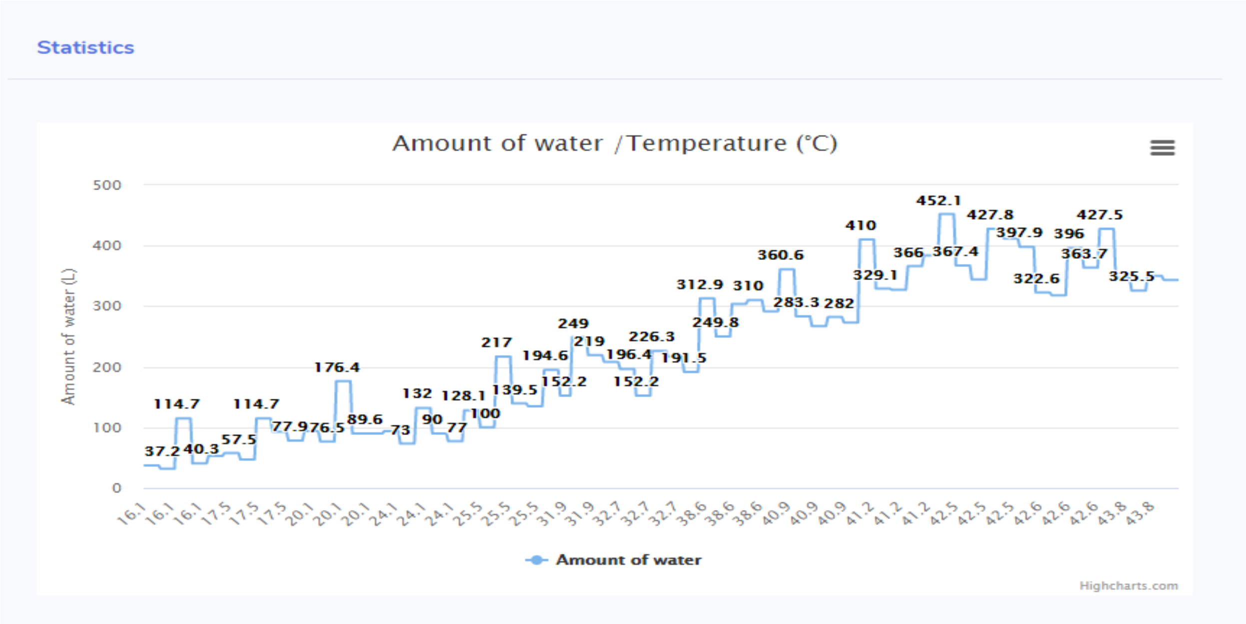
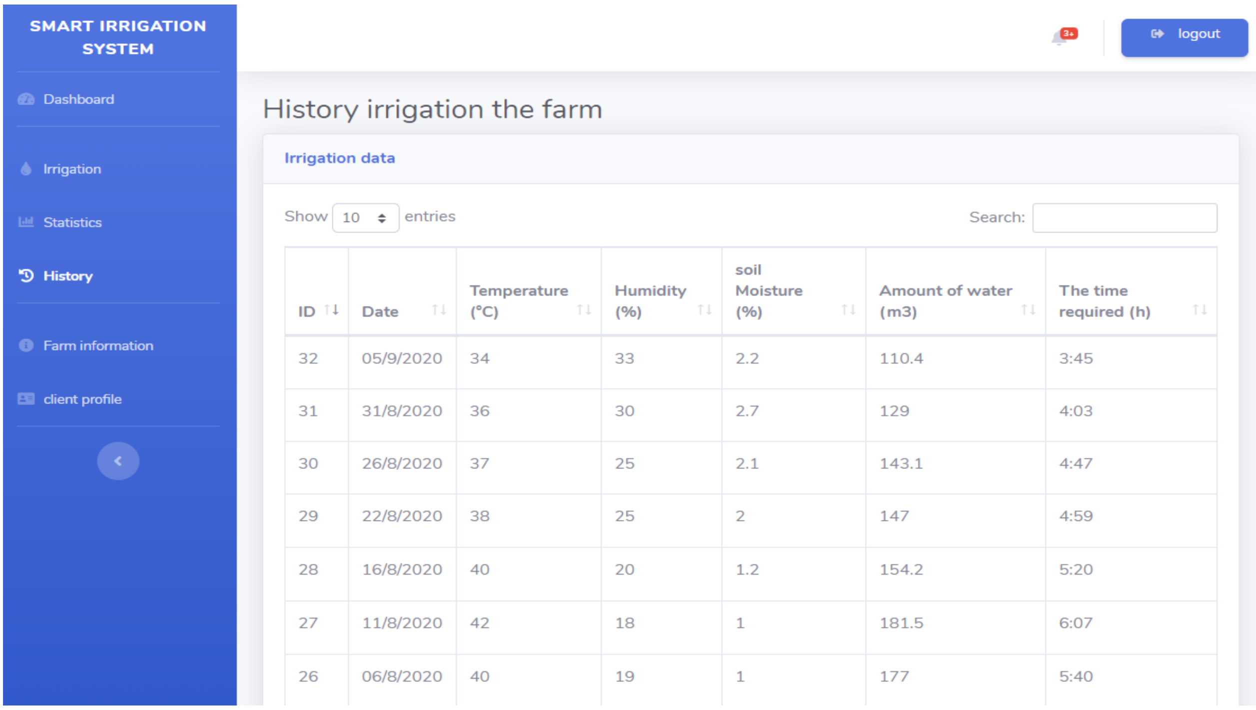


Figure 4. 6: Amount of water (L) / Temperature (°c)

4.4.4 Logs

The Logs page contains a table in which all the information related to the irrigation operations carried out by the smart irrigation system is complete with all the data such as the date of the irrigation process, the temperature and humidity at that time, and the irrigation time as well.



ID	Date	Temperature (°C)	Humidity (%)	soil Moisture (%)	Amount of water (m3)	The time required (h)
32	05/9/2020	34	33	2.2	110.4	3:45
31	31/8/2020	36	30	2.7	129	4:03
30	26/8/2020	37	25	2.1	143.1	4:47
29	22/8/2020	38	25	2	147	4:59
28	16/8/2020	40	20	1.2	154.2	5:20
27	11/8/2020	42	18	1	181.5	6:07
26	06/8/2020	40	19	1	177	5:40

Figure 4. 7: Logs page

4.4.5 Farm information

On this page, the customer will find general information about his farm, such as the geographical location, there is a map that shows the exact location of the farm, the number of palms, and how old the palm is as well.

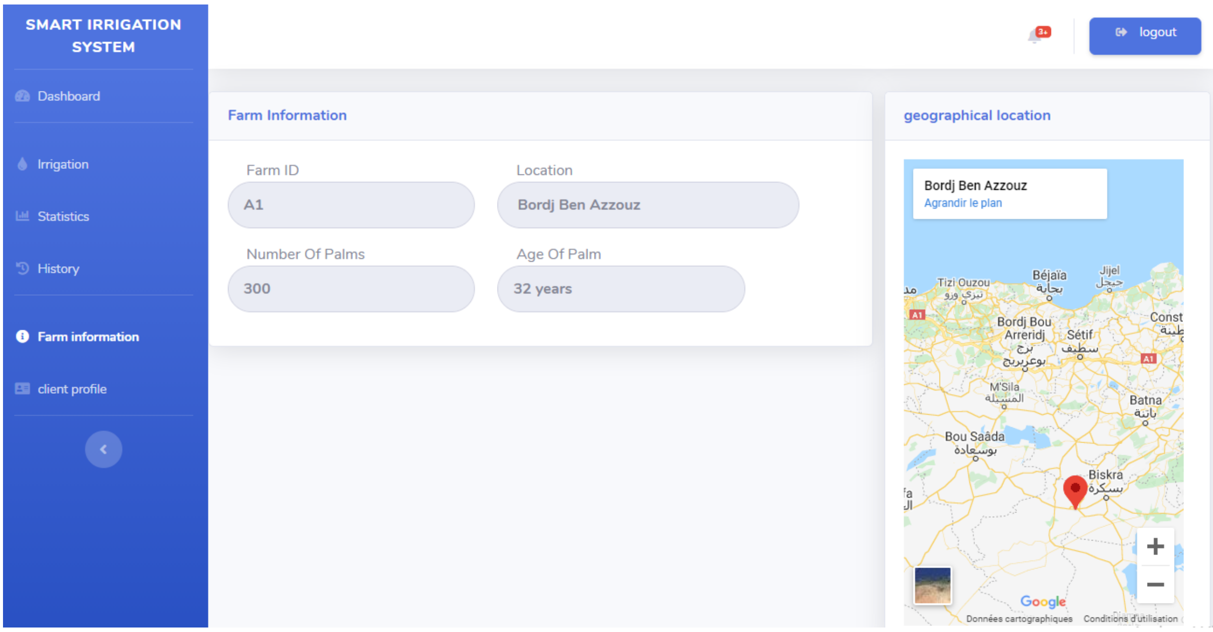


Figure 4. 8: Farm information

4.4.6 Client profile

This page allows the customer to view his personal information from his e-mail, user name and address, and he can change it if he wants to.

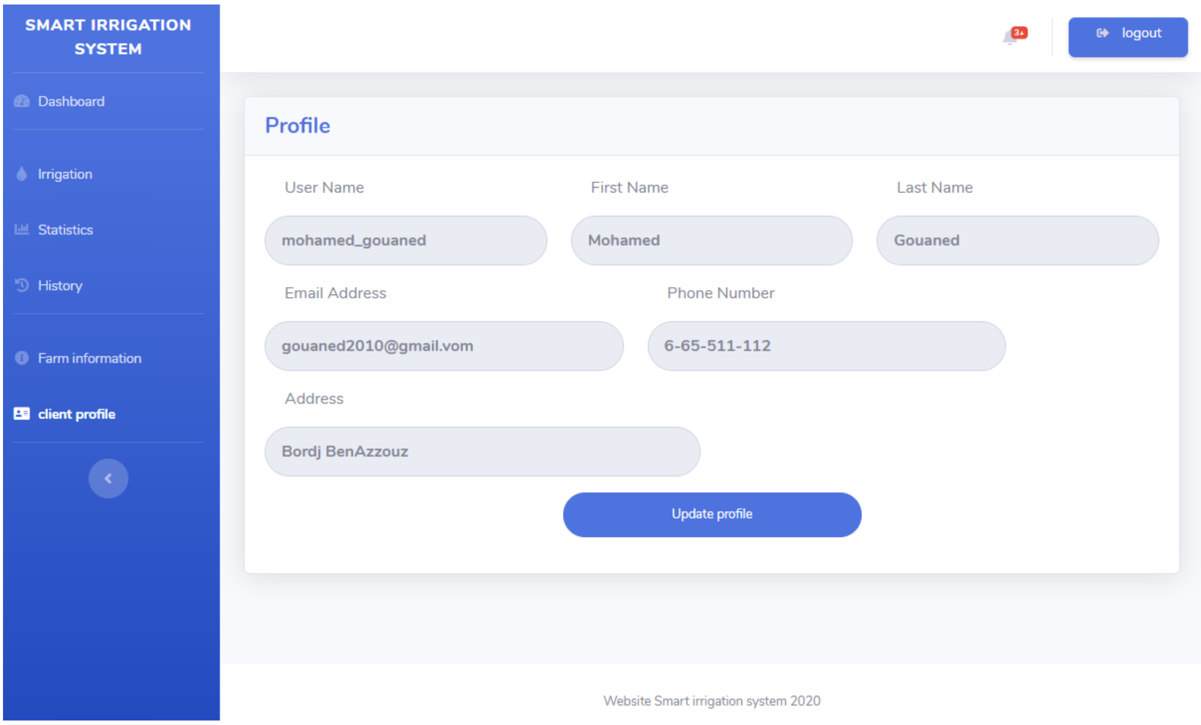


Figure 4. 9: Client profile page

4.4.7 The Admin web page

This page appears for the admin who can see all customers and their personal information and is authorized to add a new customer.

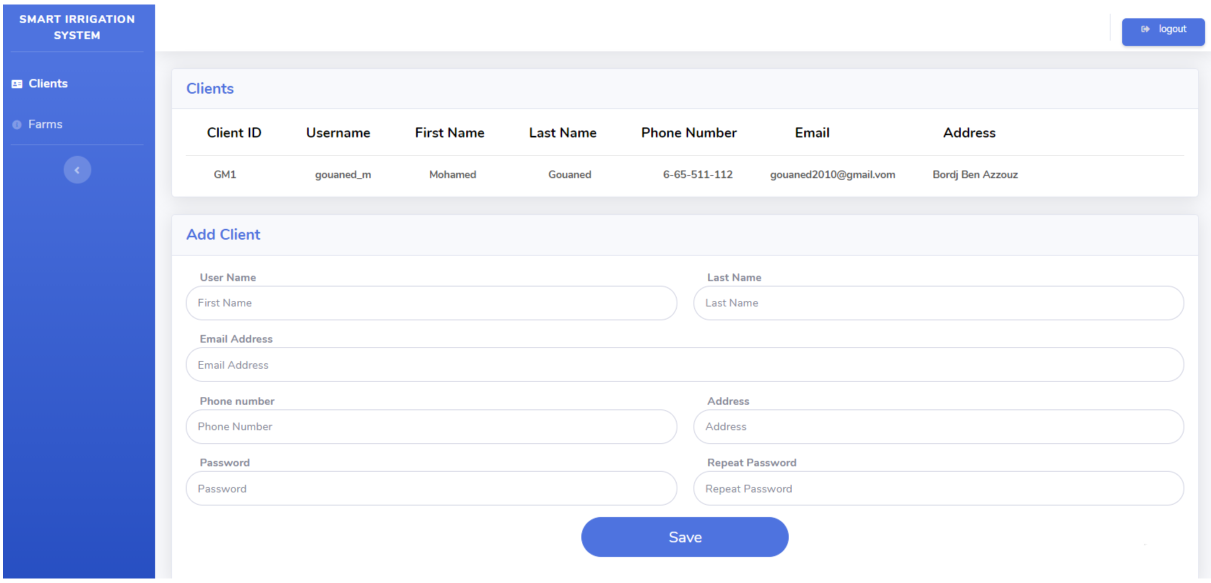


Figure 4. 10: The Admin web page (List of customers)

This page appears for the administrator in which he finds all the farms associated with the smart system and general information about them, and he is authorized to add a farm to the database.

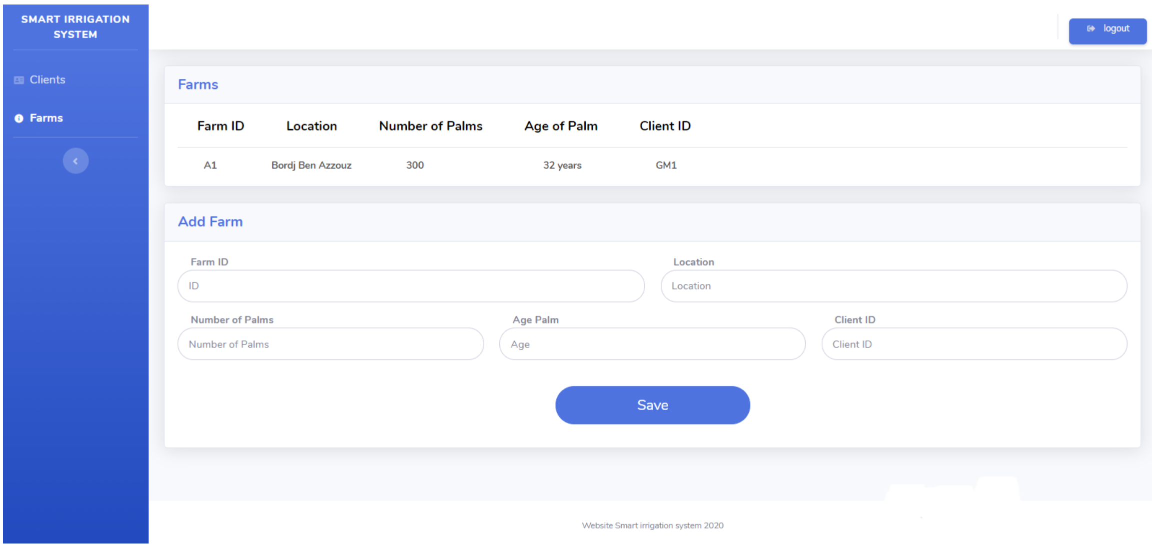


Figure 4. 11: The Admin web page (List of farms)

4.5 CASE STUDY

Note:

In our study, I had no luck finding a database for the first model through which our system learns, and for you in the second model, we used the database that appears in (Table 7) below.

4.5.1 Data

The data were obtained from a study conducted by the College of Agriculture at Anbar University in Iraq by professors Issam Khudair Hamza Al-Hadithi, Jamal Nasser Abdul Rahman Al-Saadoun, Aman Ibrahim Abdul-Hassan Al-Oqabi [26], and this study consists in calculating the amount of water needed for palm trees, depending on Several factors are temperature, coefficient KC and evapotranspiration at that time.

This study was conducted at the entrance to the city of Kut and under the climatic conditions of the central region of Iraq, the reference water consumption in this study (evaporation basin) was used as an experimental equation.

Table 6: table of data used

ID	Temperature	Evapotranspiration	KC	Amount of water
0	41.2	18.3	0.25	300
1	42.5	20.4	0.24	224.1
2	43.8	15.8	0.24	83
3	40.9	13	0.28	56.8
4	32.7	8.8	0.34	30
5	24.1	3.2	0.15	13.8
6	17.5	3.1	0.23	20
7	16.1	2.1	0.20	25.6
8	20.1	4.0	0.29	56.5
9	25.5	5.4	0.34	102.6
10	31.9	8.7	0.58	102.6
11	38.6	13.4	0.69	125.4
12	42.6	17.3	0.69	114
13	41.2	18.3	0.25	300
14	42.5	20.4	0.24	224.1
15	43.8	15.8	0.24	83
16	40.9	13	0.28	56.8
17	32.7	8.8	0.34	30
18	24.1	3.2	0.15	13.8
19	17.5	3.1	0.23	57.5
20	16.1	2.1	0.20	37.2
21	20.1	4.0	0.29	93.7
22	25.5	5.4	0.34	128.1
23	31.9	8.7	0.58	194.6
24	38.6	13.4	0.69	312.9
25	42.6	17.3	0.69	397.9
26	41.2	18.3	0.28	410
27	42.5	20.4	0.27	452.1
28	43.8	15.8	0.25	427.5
29	40.9	13	0.30	360.6
⋮	⋮	⋮	⋮	⋮

4.5.2 Artificial neural network training

The ANN consisted of an input layer with three neurons, an interlayer with one neuron and an output layer with one neuron. At the input layer, temperature (T), evapotranspiration (EV) , coefficient KC and amount of water (AOW) was determined as the output parameter.

The data set was divided randomly into a training data set (80%) and the rest was used for testing (20%) to ensure the validity of the model.

4.5.3 The law of learning

Through the study conducted by (Daniel Klerfors, Dr Terry L. Huston) [29], we find that using the Delta Learning Law to train the algorithm that achieves successful results in the classification process will be easier to deal with due to its simplicity in the field of experimental artificial intelligence.

Backpropagation: is a training algorithm based on the recalculation of bias weights and weights between the model layers to quickly reduce the error in feedforward multi-layer perceptron neural networks. The basic logic is to multiply each neuron in the layers by the weight values where it is connected to the following neuron, thus finding the net value of the neuron in the other layer. Net values of the interlayer neurons.[27]

This table is part of the training data, where we chose values for the inputs with the outputs related to them.

Table 7: ANN training set

ANN		Set1	Set2	Set3	Set4	Set5	Set6	Set_n ...
Input	**T**	31.9	42.6	37.6	32.7	31.9	38.6	…
	EV	8.7	17.3	17.3	8.8	8.7	13.4	…
	KC	0.54	0.75	0.88	0.31	0.43	0.8	…
output	**AOW**	113.4	300	309.7	60	83	243	…

Notes: T, temperature (°C); EV, evapotranspiration (%); KC, coefficient; AW, Amount of water tree (L)

4.5.4 Experimental results

The trained ANN was tested using a set of data shown in Table 7 and using IBM spss statistics to analyze the training data for the neural network, and the irrigation levels resulting from the training were determined. The system is arranged to determine the amount of water for the irrigation process. The network's success was rated at 95% confidence interval. As for the error, it was E = 0.005. The date palm tree irrigation schedule was obtained as shown in Table 8, so when we studied the results we noticed that they change with the change of the three inputs in varying proportions such as the amount of the extracted water is affected by the temperature, as well as the evapo transpiration at that time. And the parameter KC, which also affects the

result.

Table 8 represents part of the test data (20%), where we chose the input values with the outputs related to them, and we note in the last box of the table the presence of the results obtained after the training of the system.

Table 8: ANN Testing Set

ANN		Set1	Set2	Set3	Set4	Set5	Set6	Set_n …
Input	**T**	41.2	42.5	43.8	32.7	24.1	17.5	…
	EV	18.3	20.4	175.8	8.8	3.2	3.1	…
	KC	0.25	0.24	0.24	0.34	0.15	0.23	…
output	**AOW**	102	108	102	67	14	13.4	…
output	**ANN**	102.0027	108.0031	102.0023	67.0041	13.9974	13.007	

Notes: T, temperature (°C); EV, evapotranspiration (%); KC, coefficient; AW, Amount of water tree (L) ; ANN, The results obtained.

Table 9: Parameter estimates

predictor		Hidden layer	Output layer
		H(1,1)	
Input layer	bias	-0.928	
	T	0.398	
	EV	0.156	
	KC	0.349	
Hidden layer	bias		1.403
	H(1,1)		2.383

This table shows the value of the weights that allow us to specify the desired results with a minimal error value.

bias = -0.928 , W0 = 0.398 , W1 = 0.156 , W2 = 0.349;

bias = 1.403 , W3 = 2.383;

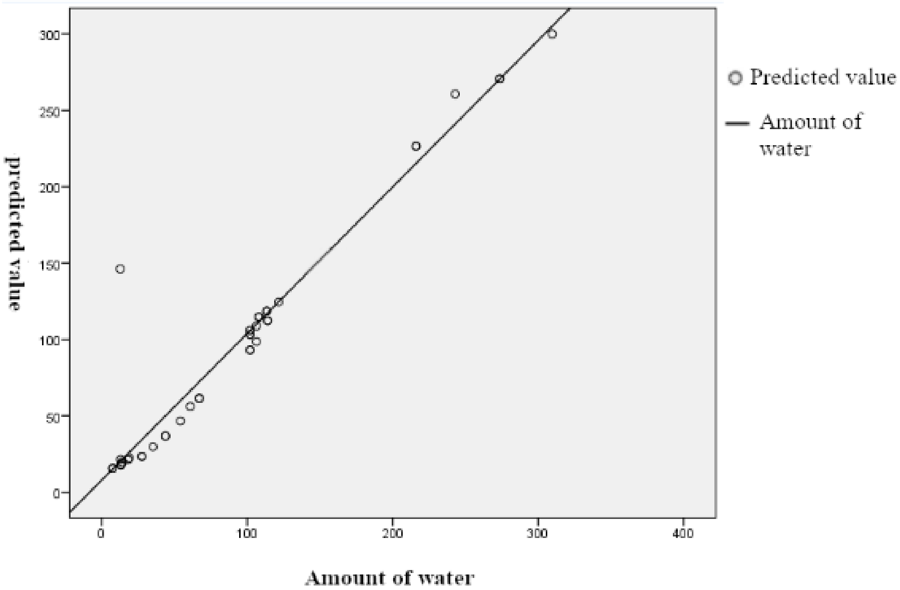


Figure 4. 12: Estimated / observed graph

The curve above represents the expected value of the system for the amount of water compared to the output, we note that the expected values are close to the output values and this is because the error rate is small.

As for energy saving and water rationalization, we note through a study conducted by Dr. Esmaiel Malek [30] that evapotranspiration decreases at night and increases its intensity during the day, which is an important input. When its density increases, the amount of water consumed for irrigating palm trees increases, and for this we suggest that the irrigation process be at night. In this way, energy consumption is decreased, as well as water consumption rationalization.

4.6 Conclusion

In this chapter, we showed everything related to our system, the programming languages, the web portal that allows the customer and the supervisor to inspect and monitor the farm.

Moreover, monitor the progress of our system that irrigates the farm in an intelligent way without human intervention using Machine Learning technics.

General Conclusion

Artificial intelligence has spread in all areas, including health, transportation and agriculture, and therefore artificial intelligence must be developed in agriculture, which is the main source of food.

Today AI-powered technologies are used for solving several industries' purposes. AI is being utilized in sectors such as finance, transport, healthcare, and now in agriculture. AI is helping the farmers to monitor their crops without the need to invigilate personally into the farm. Many startups and enterprises are looking forward to AI development in agriculture. AI is redefining the traditional pattern of agriculture. The future of AI in agriculture is way ahead in offering radical transformation with advanced approaches. [28]

We must improve the traditional methods of the agricultural irrigation system in all regions, especially the dry areas that suffer from scarcity of rain and a scarcity of groundwater. In the current era, farmers use traditional manual methods of irrigation at regular, unexplained periods, and this process consumes water in a way. It is large and leads to its waste in an irrational way, and causes a decline in the quality and quantity of the crop, and for this we suggest that artificial intelligence and the Internet of things enter agriculture directly and strongly, to keep pace with the development taking place in the developed world, this will help us to exploit our energy and our lands while soaking us.

This project will help farmers and facilitate the irrigation process for them, which is actually difficult in dry areas, as our system will have intelligent self-control in irrigating palm trees to reduce the wasting of good water and the efforts made depending on artificial intelligence.

Future works

We have faced some obstacles in implementing our project on the ground. Among these obstacles is the lack of sufficient databases to enable us to training our system when the irrigation process will take place.

We look forward to improving this work by providing a database as well as field work using the Internet of Things. In order to create a reliable integrated system for irrigation.

References

[1] TanhaTalaviya, Dhara Shah, Nivedita Patel, Hiteshri Yagnik, MananShah, "Implementation of artificial intelligence in agriculture for optimisation of irrigation and application of pesticides and herbicides", Artificial Intelligence in Agriculture Volume 4, 2020, Pages 58-73, April 22, 2020.

[2] Marco Zennaro, "Introduction to the Internet of Things", PhD Telecommunications/ICT4D Lab the Abdus Salam International Centre for theoretical Physics Trieste, Italy, May 11, 2018

[3] "Internet of things", wikipedia, 2018 (https://en.wikipedia.org/wiki/Internet_of_things)

[4] Margaret Rouse, "Cutting edge: IT's guide to edge data centers", IoT Agenda, February 2020 (https://internetofthingsagenda.techtarget.com/definition/Internet-of-Things-IoT)

[5] Jen Clark, "What is the Internet of Things (IoT)?", November 17, 2016 (https://www.ibm.com/blogs/internet-of-things/what-is-the-iot/)

[6] "What is IoT architecture?", avsystem, May 11, 2020 (https://www.avsystem.com/blog/what-is-iot-architecture/)

[7] Srishti Rawal, "IOT based Smart Irrigation System", International Journal of Computer Applications (0975 – 8887) Volume 159 – No 8, February 2017

[8] Shuzlina Abdul Rahman, Izham Fariz Ahmad Jinan,Ku Shairah Jazahanim, Azlinah Mohamed, "Intelligent Water Dispersal Controller Using Mamdani Approach", Faculty of Information Technology & Quantitative Sciences Universiti Teknologi MARA 40450 Shah Alam Selangor, malaysia , June 19-21, 2007

[9] Water in Agriculture, May 08, 2020 (https://www.worldbank.org/en/topic/water-in-agriculture)

[10] Nita Karume, Top pump systems for modern agriculture, 16 juil.2018 (https://www.pumps-africa.com/top-pump-systems-for-modern-agriculture/)

[11] Watering palm trees,Aug 22,2019 (https://www.aghapack.com/Ar/BlogDetail?id=5)

References

[12] Deepak Sinwar, Vijaypal Singh Dhaka, Manoj Kumar Sharma, Geeta Rani, "AI-Based Yield Prediction and Smart Irrigation", Internet of Things and Analytics for Agriculture, Volume 2 pp 155-180, 25 October 2019

[13] Mr. Kotresh Marali, "smart irrigation system using internet of things" , Department of Electronics and Communication Engineering An autonomous Institution affiliated to Visvesvaraya Technological University, Belgaum-india , May 2016.

[14] Srishti Rawal, "IOT based Smart Irrigation System", International Journal of Computer Applications (0975 – 8887) Volume 159 – No 8, February 2017

[15] Remi Schmaltz, "What is Precision Agriculture?", AgFunder Network Partners, April 24, 2017 (https://agfundernews.com/what-is-precision-agriculture.html)

[16] "Precision Irrigation Flow Meters Help Farmers Conserve Resources", New Mexico State University, (https://www.seametrics.com/blog/precision-irrigation/)

[17] D. Dubost, "Micro irrigation des palmiers dattiers" , Department of Agronomic Sciences, Biskra, 2008.

[18] Caroline Prevot, "Evapotranspiration (ET)", 05/07/2008 (https://www.actu-environnement.com/ae/dictionnaire_environnement/definition/evapotranspiration.php4)

[19] F. Bouteldjaoui, Mohamed Bessenasse, "Etude comparative des différentes méthodes d'estimation de l'évapotranspiration en zone semi-aride (cas de la région de Djelfa)", Ziane Achour University of Djelfa, Djelfa-Algeria, June 2012

[20] Adel mihoub, Helimi samia, Mokhtari Sakher, Halitim Amor, "Evaluation of method for estimating water requirements of crops grown in saline environment (case of date palm)", Revue Agriculture. Special issue 1, 189 – 197, Semester review - Ferhat Abbas University, Setif-Algeria, 2016

[21] Ben Zientara, "Solar power rocks", Solar Basics, 04/02/2020 (https://www.solarpowerrocks.com/solar-basics/how-much-electricity-does-a-solar-panel-produce/).

[22] A. Juárez-Maldonado, A. Benavides-Mendoza, K. de-Alba-Romenus1 and A. B. Morales-Díaz, "Estimation of the water requirements of greenhouse tomato crop using multiple regression models", Emir. J. Food Agric. 2014. 26 (10): 885-897, 2014

[23] Kit Warchol, "What is python used for? Five industries that cannot do without it", 2015 (https://skillcrush.com/blog/what-is-python-used-for/)

[24] Meet Django, Django, 2017 https://www.djangoproject.com/

[25] Simran Kaur Arora, "What is PyCharm?", 06 Aug, 2020 (https://hackr.io/blog/what-is-pycharm)

[26] Issam Khudair Hamza Al-Hadithi, Jamal Nasser Abdul Rahman Al-Saadoun, Aman Ibrahim Abdel-Hassan Al-Oqabi, "Water requirements for date palm seedlings (Medjool and Khalas), tissue proliferating and cultivated under the climatic conditions of central Iraq" Anbar Journal of Agricultural Sciences Volume 31 Issue ISSN: 1992-7479 5132, Anbar-Iraq, 2015

[27] ahmed fawzy gad, "Backpropagation: understanding how to update ANNS weights step-by-step", Menoufia University faculty of computers and information technology, menoufia-Egypt, May 25, 2017

[28] Jyoti Gupta, "The Role of Artificial intelligence in Agriculture Sector", customer think, October 11, 2019, (https://customerthink.com/the-role-of-artificial-intelligence-in-agriculture-sector/)

[29] Daniel Klerfors, Dr Terry L. Huston, "Artificial Neural Networks", An individual project within MISB-420-0, Saint Louis University, November 1998

[30] Esmaiel Malek, "Night-time evapotranspiration vs. daytime and 24h evapotranspiration", Article in Journal of Hydrology, Amsterdam, September 1992