



People's Democratic Republic of Algeria
Ministry of Higher Education and Scientific Research



University of Ahmed Ben Bella, Oran 1
Institute of Applied Sciences and Technologies, ISTA

Master Thesis

In preparation for obtaining a diploma

Master's degree in Instrumentation and metrology

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Theme

An IOT Irrigation System using machine Learning

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Academic year: 2023/2024

Acknowledgements

Praise be to Almighty God, who has given me the faith, courage, and patience to carry out this work. I would like to extend my heartfelt thanks to everyone who has supported me throughout this project. I thank my father for providing the initial idea for this project, which I proudly present to him as a gift. I also extend my gratitude to my supervisors, Dr. Cheriet Mohammed Amine and Dr. Dahane Amine, for their guidance and support. Additionally, I wish to express my sincere thanks to Mr. Boudia for his invaluable assistance in finalizing the project design.

I am deeply grateful to the faculty and administrators of the Institute of Applied Sciences and Technologies (ISTA) for equipping me with the necessary knowledge over five years of study.

To all these individuals, I offer my profound thanks, respect, and gratitude.

Dedications

I dedicate this work to the source of my tenderness, the light of my life, my mother. To my father, who is the reason I am who I am today—I owe it all to you. Your unwavering support and countless sacrifices mean the world to me. To all my brothers and sisters, thank you for being my pillars of strength in every situation and for standing by my side during difficult times. I wouldn't know how to manage my affairs without the invaluable advice and guidance from my generous family. To all my loved ones, and finally, to myself.

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Abbreviations list

PA:precision agriculture

IOT: internet of things

SDGs: Sustainable Development Goals

SDI:Sub surface drip irrigation

SDI: the stress day index,

NCS: Factors of normalized crop susceptibility

ET: the Evapotranspiration

PP: Proposed Platform

LORA: short for Long-Range

ML: machine learning

AI: Artificial Intelligence

KNN:K- nearest neighbor

RMSE:Root Mean Squared Error

MSE:Mean Squared Error

MAE: Mean Absolute Error

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Abstract

This master thesis presents a smart irrigation system for small farmer communities (SFCs) designed to optimize water use in agriculture through advanced sensor technologies and machine learning (ML) techniques. The system employs Internet of Things (IoT) components, including low-cost sensors such as the capacitive gravity SEN0308, water tension irrometer watermark, and DHT22. An Arduino Uno collects sensor data and transmits it via LoRa communication to an Arduino Mega 2560, which controls a valve and water flow sensor. ML integration enables real-time analysis and decision-making to prevent over-irrigation by considering soil moisture, temperature, humidity, and historical patterns. The system enhances water efficiency, reduces labor costs, and improves crop yields, thereby contributing to sustainable agricultural practices.

Keywords: Internet of Things, Irrigation, Low-Cost sensors, Machine Learning, Smart Farming.

ملخص

تقدم هذه الرسالة نظام ري ذكي لمجتمعات المزارعين الصغار (SFCs) مصمم لتحسين استخدام المياه في الزراعة من خلال تقنيات أجهزة الاستشعار المتقدمة وتقنيات تعلم الآلة (ML). يستخدم النظام مكونات إنترنت الأشياء (IoT)، بما في ذلك أجهزة استشعار منخفضة التكلفة مثل المستشعر الجاذبي السعوي SEN0308، مقياس التوتر المائي irrometer watermark، ومستشعر DHT22. يجمع جهاز Arduino Uno بيانات المستشعر وينقلها عبر اتصال LoRa إلى Arduino Mega 2560، الذي يتحكم في صمام ومستشعر تدفق المياه. يتيح تكامل تعلم الآلة (ML) تحليل البيانات في الوقت الفعلي واتخاذ القرارات لمنع الري الزائد من خلال مراعاة مستوى رطوبة التربة، درجة الحرارة، الرطوبة، والأنماط التاريخية. يعزز النظام كفاءة استخدام المياه، يقلل من تكاليف العمالة، ويحسن من إنتاجية المحاصيل، مما يساهم في ممارسات زراعية مستدامة.

الكلمات المفتاحية: إنترنت الأشياء، الري، أجهزة استشعار منخفضة التكلفة، تعلم الآلة، الزراعة الذكية

General Introduction

Agriculture, as a cornerstone of global food security, faces escalating challenges in optimizing water usage amidst increasing demands and climate uncertainties. Traditional irrigation practices often result in inefficient water allocation, leading to significant waste and suboptimal crop yields. In response, smart irrigation systems have emerged as innovative solutions, integrating advanced sensor technologies and machine learning techniques to precisely manage water distribution based on real-time data and crop requirements. By harnessing Internet of Things (IOT) components and machine learning techniques (ML), these systems promise enhanced water efficiency, reduced labor costs, and improved agricultural productivity. This study focuses on the development and implementation of such a system tailored for small farmer communities (SFCs), highlighting its potential to revolutionize sustainable farming practices and mitigate water scarcity challenges in agriculture.

Problematic

In recent years, drought and persistent lack of rainfall have increasingly become year-round challenges, significantly impacting agriculture, the country's second most vital economic sector. Consequently, farmers have increasingly turned to groundwater and alternative irrigation methods to sustain their crops. However, a significant issue arises from excessive water usage, which not only fails to optimize irrigation but also jeopardizes crop health. This raises a fundamental question: How can we achieve crop sufficiency while minimizing costs effectively and saving water?

Organization of the thesis:

The thesis is structured into three chapters, focusing on the study and implementation of smart irrigation technology, along with strategies for market deployment:

Chapter 1: Precision Agriculture Technology

This chapter provides an in-depth exploration of real-time irrigation systems within the framework of precision agriculture. It examines various techniques and methodologies aimed at improving water use in agricultural practices with existing literature and research efforts related to smart irrigation systems. It discusses key findings, methodologies and technological developments in the field of smart agriculture.

Chapter 2: Design and Development of the Proposed Smart Irrigation Platform

This chapter details the conceptualization and implementation of the proposed smart irrigation platform. It covers the design principles, sensor integration, data analytics, and decision-making processes essential for efficient water management in agricultural settings.

Chapter 3: Marketing Strategy

The final chapter explores strategies for marketing and promoting the smart irrigation system. It discusses market analysis, target audience identification, competitive positioning, and promotional tactics aimed at facilitating widespread adoption and commercial success.

CHAPTER I:

Precision Agriculture Technology

Chapter I: Precision Agriculture Technology

Introduction

Precision agriculture technology is an intelligent agricultural system that uses sensors and monitoring technologies to obtain the necessary data about the land based on environmental factors that affect crop growth. By providing the right amount of resources in a specific period of time such as water, light, pesticides...IOT (Internet of Things) is applied in precision agriculture to collect information about crop production and regulate it in time and operability.

We find it in several applications, the most important of which is: water quality monitoring, irrigation management system, drones for field monitoring and machine for routine operations. But in this chapter, we will see it in irrigation management.

Irrigation is considered the main factor in agriculture, as agriculture represents approximately 70% of global water use annually. It has been known in several civilizations for more than 5,000 years and developed by many cultures around the world. It is used to provide water to crops and protect them from frost, and also to suppress the growth of harmful weeds in grain fields and prevent soil hardening.

Irrigation is the industrial exploitation of soil water using various methods such as pumps, pipes and sprinklers. Which we see in the main irrigation methods namely: surface, sprinkler, drip irrigation and Sub-Surface drip irrigation. Each method has its own merits and demerits, depending on the soil, topography, type of crops, climate, water availability and quality, and investment, which are the guiding factors for selecting an adequate irrigation method. The need for irrigation usually appears in places where rainfall is irregular, or in times of drought, or in places where drought is regular. The water is conserved when implementing these technologies in irrigation systems such that it plays an important contributor to Sustainable Development Goals (SDGs).

In recent years, revolutionary developments have taken place in irrigation practice. A more comprehensive understanding has evolved of the interactive relationships among the soil, plant, and climate regarding the disposition and utilization of water. These scientific developments have been paralleled by a series of technical innovations in the methodology of water control

Chapter I: Precision Agriculture Technology

who knows smart irrigation or automatic irrigation, have made it possible to establish and maintain nearly optimal soil moisture conditions continuously. [1]

An IOT-based smart irrigation system is designed to maintain a balance in the water level of the field. It turns the water pump 'on' when the field is dry and turns it 'off' when it is wet.

I. Precision agriculture

Precision agriculture is a term that encompasses general agriculture but this time with precision in the entire value chain of food products starting with the type of soil, climate, and irrigation methods, amount of water used, and crop recovery. To ensure this, we will need the different tools available to have a precised agriculture or agriculture of the future.

In recent years, the industry ecosystem has invested in innovation in terms of technological development, focusing mainly on low-cost and highly efficient actions in terms of production with knowledge-based development. [2] Which Data is collected in real time via sensors in the fields that measure moisture content and temperature of the soil and ambient air, and display it on phone or computer screen.

II. Irrigation systems and sustainability

Sustainability could be considered as an essential aspect that is related to irrigation systems. To maintain the sustainability within any system, balance between the three pillars of sustainability should be ensured. The three pillars of sustainability are economic, social, and environmental. Fig.1 shows the potential economic, environmental, and social impact of irrigation systems.

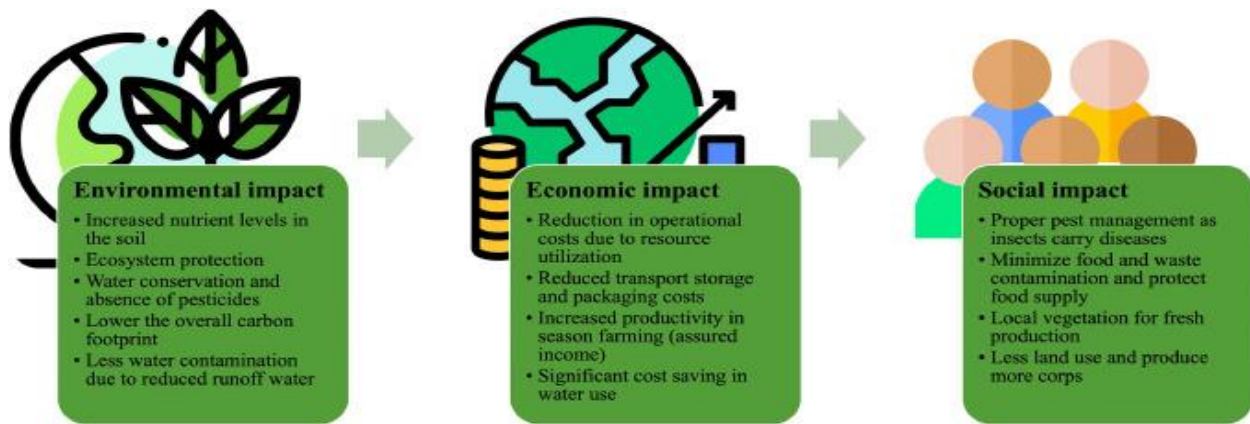


Figure I.1: Potential economic, environmental and social benefits of the irrigation system

The elements of sustainability could be assessed in different contexts and mediums and so these considerations need to be made by the organizations involved in the particular sector and related work. One of the aspects of sustainability is related to ensuring that the irrigation activities do not impact the environment negatively. [3]

III. Methods of Irrigation

There are several methods of irrigation which vary in how the water is supplied to the plants. The goal is to apply the water to the plants as uniformly as possible, so that each plant has the amount of water it needs, neither too much nor too little.[4]

Various irrigation methods have been developed over time to meet the irrigation needs of certain crops in specific areas. The four main methods of irrigation are surface, subsurface, sprinkler and drip/micro irrigation as shown in Figure.2. [5]

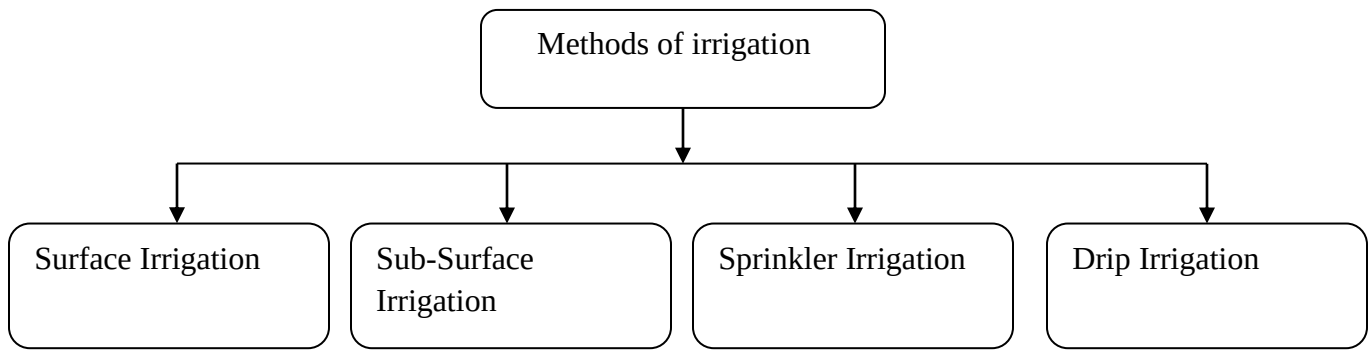


Figure I.2. The main techniques of irrigation

III.1 Surface irrigation:

It is the irrigation technique in which water is applied and distributed over soil surface by gravity; it is the most common form of irrigation method throughout the world. [6]



Figure I.3. Surface technique

CHAPTER I: Precision agriculture technology

Advantages and Disadvantages of sprinkler irrigation

Advantages	Disadvantages
• Uniform application of water can be possible. • Irrigation is better controlled. • More land will be available for cropping as borders and ditches are not required. • Labor cost is reduced. • Surface runoff is eliminated. • Small streams of irrigation water can be used efficiently.	• Wind may distort sprinkler pattern and sprinkler network too. • Water must be clean and free from sand or other dust particle (to prevent blockade of sprinkler notches).

Table I.2.Advantages and disadvantages of sprinkler irrigation

III.3 Center pivot:

Sprinkler can also be mounted on moving platforms connected to the water source by a hose. Automatically moving wheeled systems known as traveling sprinklers may irrigate areas such as small farms, and pastures centuries unattended.

This type of system is known to most people as a (water reel) traveling irrigation sprinkler and they are used extensively for dust suppression, irrigation, and land application of waste water. [4]



Figure I.5.center pivot with drop sprinklers



Figure I.6.rotator style pivot application sprinkler

Advantages and disadvantages of Center pivot

Advantages	Disadvantages
• Precise Application of Water the center pivot irrigation system applies water to exactly where it is needed on the farm. This reduces the risk of runoffs and erosion. This type of irrigation system also ensures good water infiltration into the soil. • Savings in Labor Needs the center pivot significantly reduces the need for human labor for irrigation schedules. The high automated nature of the center pivot ensures that a single person can irrigate large acreages of farmland without the need for a lot of human intervention. • Longevity the average lifespan of a center pivot is 20 years. If you use a centre pivot irrigation system, you are not likely to replace it for 20 years. This can significantly reduce the cost of operations in a farm. • Low Operation and Maintenance Cost Center pivots are quite rugged.	• High Cost of Acquisition the cost of acquisition of a center pivot irrigation system is usually high. A single center pivot in Nigeria can be priced as high as N30 million. This is one of the demerits of using a center pivot. • High Energy Requirement the center pivot needs power like electricity. The KW of electricity needed by the center pivot irrigation system is usually high, that makes it expensive. • Technical Knowhow needed the center pivot is a complex type of irrigation system. The technical knowhow needed to operate the center pivot may not be easy to come by.

Table I.3. Advantages and disadvantages of center pivot

III.4 Drip irrigation (localization):

Drip irrigation is also known trickle irrigation in this method the water is applied in a form of drops directly near of the plant and it is one of the latest developed methods of irrigation which is more popular in the regions facing scarcity of water. [6]



Figure I.7.Drip technique

Advantages and Disadvantages of Drip irrigation

Advantages	Disadvantages
• High water application efficiency and lower labor costs. • Minimized fertilizer/nutrient loss due to localized application and reduced leaching. • Ability to irrigate irregular shaped fields. Leveling of the field is not necessary • Allows safe use of recycled (waste-) water • Moisture within the root zone can be maintained at field capacity and minimized soil erosion • Soil type plays less important role in frequency of irrigation • Highly uniform distribution of water i.e., controlled by output of each nozzle	• Expensive initial cost can be more than overhead systems (commercial system). • The sun can affect the tubes used for drip irrigation, shortening their usable life. • If the water is not properly filtered and the equipment is not properly maintained, it can result in clogging. • Drip irrigation might be unsatisfactory if herbicides or top dressed fertilizers need sprinkler irrigation for activation. • Waste of water, time & harvest, if not installed Properly. • Systems require careful study of all the relevant factors like land topography, soil, water, crop and agro-climatic conditions, and suitability of drip irrigation system and its components.

Table I.4.Advantages and disadvantages of drip irrigation

III.5 Sub surface irrigation:

Subsurface drip irrigation is a low-pressure, high efficiency irrigation system that uses buried drip tubes or drip tape to meet crop water needs. Subsurface irrigation saves water and improves yields by eliminating surface water evaporation and reducing the incidence of weeds and disease. [7]

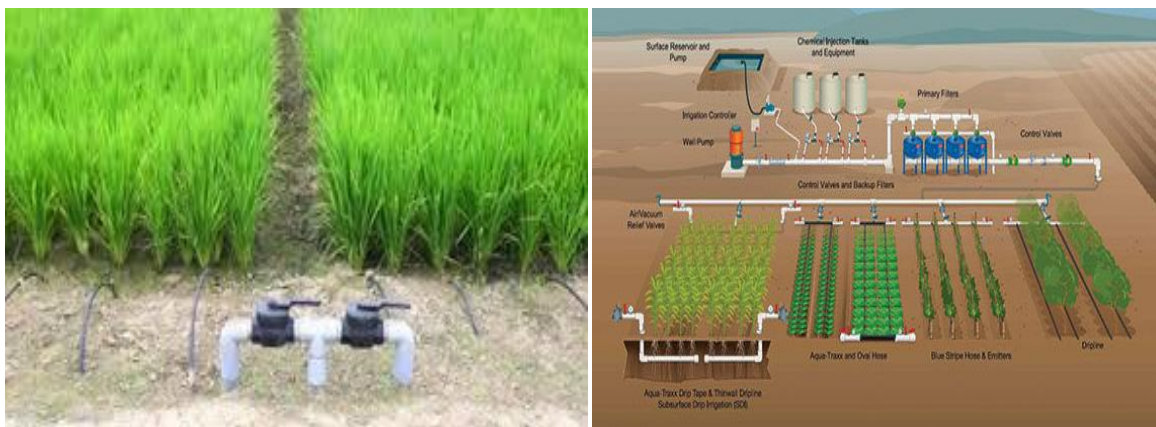


Figure I.8. Subsurface drip technique

Advantages and Disadvantages of Sub surface irrigation

Advantages	Disadvantages
• High degree of control over water application with the potential for high uniformity of application. • Evaporation is reduced. • The amount of water can be fine-tuned. This avoids water loss caused by run off or evaporation. • Frequent irrigation allows for optimum soil moisture content in the root zone. • Great performance in windy and arid locations. • If pre-treated wastewater is used for irrigation, the risk of direct contact with crops and laborers is reduced.	• Risk of clogging. • When saline water is used, salts accumulate at the wetting front. • Emitter can be damaged or blocked by root hairs. • Bacterial slimes and algae growing on the interior walls of the laterals and emitters combined with clay particles in the water can block the emitters. • Suspended organic matter and clay particles can damage the system. • A lot of repair work is caused by rodents chewing the tubes Heavy machinery

Table I.5. Advantages and disadvantages of sub surface irrigation

IV. Comparing the irrigation methods

To choose an irrigation method, a farmer must know the advantages and disadvantages of different methods. In many cases there is no single best solution: all methods have their advantages and disadvantages. Testing different methods under prevailing local conditions provides the best basis for proper selection of irrigation method.

The suitability of different irrigation methods (i.e. surface, center pivot, sprinkler, drip or SDI) depends mainly on the following factors:[8]

- Natural conditions.
- Crop type.
- Type of technology.
- Previous experience in irrigation
- Labor input required.
- Costs and benefits.

This table offers an easy comparison between the major types of irrigation:

Type of irrigation	Surface	Sprinkler	Center pivot	Drip	Sub surface drip irrigation
Suitable for	Flat areas, various crops	Landscaping, various crops	Large-scale agriculture	Horticulture, large-scale agriculture, landscaping	Horticulture, large-scale agriculture, landscaping
Water efficiency	Moderate	Moderate to high	High	Very high	Very high
Initial setup cost	Low	Moderate	High	Moderate to high	Moderate to high
Operating cost	Low	Moderate	Moderate	Low	Low
Nutrient management	Low precision	Moderate precision	High precision	Very high precision	High precision
Adaptability to different environments	Limited	Moderate	High	High	Limited
Maintenance Requirements	Moderate	Moderate	Moderate	Moderate	Low

Table I.6. Comparison between the major types of irrigation

V. Irrigation development:

This section shows how irrigation has changed throughout time from 1970 through 2022, in four separate periods. Researchers were interested in irrigation optimization from 1970 to 1985 because of the introduction of intelligent monitoring systems and water limitations for irrigation. Water usage efficiency and information were introduced in the late 1970s when water demand began to rise with population growth and natural resource depletion. The scenario necessitated the improvement of the irrigation technique, the stress day index (SDI), Factors of normalized crop susceptibility (NCS), the Evapotranspiration (ET) crop canopy, and climate variables were all recognized as important in achieving irrigation optimization. After 1989, when the Internet became available to the general public, it sparked the development of control systems based on the internet and web-based data storage. IN 2000 WSNs have begun to gain traction as a simple and effective solution for monitoring the environment. Actuators and sensors for many WSN applications, including agricultural, have been developed. WSNs value existing irrigation systems by giving the grower instant input on the crop's water requirements. Also, construct WSNs that can monitor and regulate irrigation water applications using different methods, and efficient routing protocol. Precision agriculture researchers have been paying close attention to smart applications and approaches for irrigation, soil fertilization, insect management, and disease forecasting by employing cutting-edge advanced technologies including Machine Learning (ML), Artificial Intelligence (AI), Unmanned Aerial Vehicles (UAV), and the Internet of Things (IOT). Fig. shows this progression. [9]

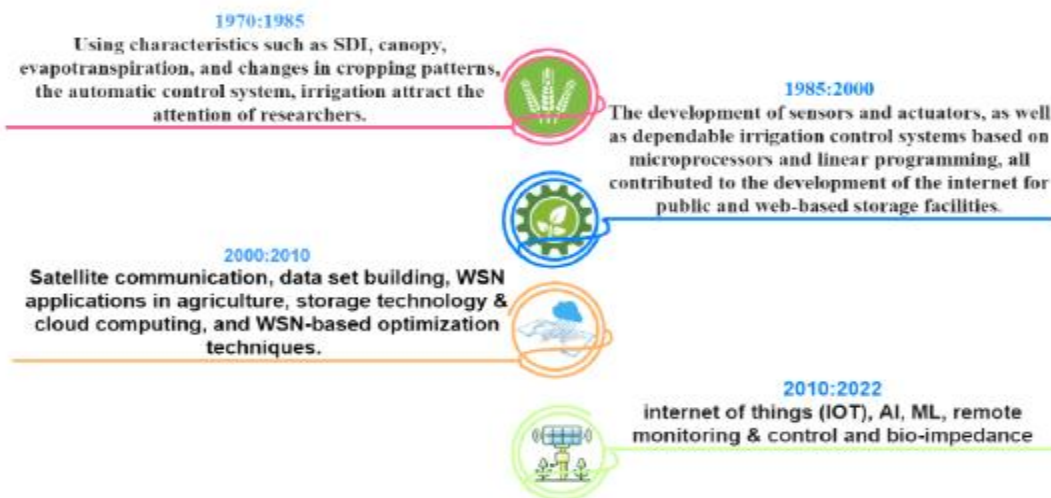


Figure I.9. Irrigation development from 1970 to present

VI. Irrigation efficiency

Irrigation efficiency is a critical measure of irrigation performance in terms of the water required to irrigate a field, farm, basin, irrigation district. The value of irrigation efficiency and its definition are important to the societal views of irrigated agriculture and its benefit in supplying the high quality, abundant food supply required to meet our growing world's population. "Irrigation efficiency" is a basic engineering term used in irrigation science to characterize irrigation performance, evaluate irrigation water use, and to promote better or improved use of water resources, particularly those used in agriculture and turf/landscape management [10]

VII. Real time irrigation scheduling systems

Through the regulation of soil moisture, Irrigation schedules that are updated in real-time aim to increase harvest yields and reduce crop water stress. However, too much water is detrimental to a variety of plants. The quantity of water needed by plants is evaluated by their growing stage, climate, and crop kind. So, Irrigation solutions that improve water efficiency are scheduled.

Statistics that measure the degree of fit were calculated by comparing dry matter, crop phenology, soil moisture, and grain yield simulation and observation. Irrigation scheduling option was tested in this study: irrigation scheduling based on soil water. In the system of soil-land-atmosphere, AI algorithms are used to understand the soil moisture dynamic behavior which would then be implemented in a low-cost controller to create efficient irrigation timelines. In order to conserve water and maintain yield. [9]

VIII. Smart irrigation

Smart irrigation is a method of using science and technology to save water in irrigation. It contains weather sensors, soil sensors and various controllers. Their sensors monitor, current weather conditions and actual ground humidity, and control the water valve to open or close. Realize automatic irrigation. Scientific judgment on when and how much water is needed. It is suitable for water-saving management in lawns, farmland, landscape and other areas.

The smart irrigation system integrates technologies such as LORA, and remotes sensing monitoring. Remotely control valve switches wirelessly. Provide plants with the right amount of water according to soil type and weather conditions to save irrigation water. The smart irrigation system mainly includes various technologies such as sensor technology, automatic control technology and computer technology. Combined with garden irrigation methods such as sprinkler irrigation and drip irrigation. [11]



Figure I.10. Smart irrigation system

IX. Smart irrigation system advantages and disadvantages

Advantages	Disadvantages
• Save manpower. Compared with traditional irrigation methods, smart irrigation is an automated method. No need for the irrigator to walk around the irrigation field with the nozzle. There is also no need to manually open or close the water valve. A mobile phone or a computer can complete the entire irrigation work. • Save water. The purpose of smart irrigation is to save water; it replaces the previous flood irrigation and uses less water to meet the growth needs of plants. Smart irrigation systems can collect soil moisture data and effectively control irrigation water. • Remote management. Use a mobile phone or computer to complete monitoring data analysis and irrigation work, you do not have to appear in the irrigation area. Just turn on the phone in the right time to observe the growth status of the plant. One person can manage multiple cloud platforms at the same time and irrigate thousands of acres of farmland, which greatly saves labor costs. • Intelligent control. Timed irrigation, remote irrigation, and cycle irrigation, flexible switching between the three irrigation modes and the cloud platform modification take effect immediately. [11]	• You should adjust irrigation the first day and check if it is adequate during the first weeks to avoid lack of irrigation or water logging. • Costs for purchasing, installing and maintaining the equipment. • Smart irrigation systems that raise water at height require the use of energy (electricity or batteries).[12]

Table I.7. Advantages and disadvantages of smart irrigation system

X. BASIC CONTROL STRATEGIES

Two general types of controllers are used to control irrigation systems: Open control loop systems, and closed control loop systems. The difference between these is that closed control loops have feedback from sensors, make decisions and apply decisions to the irrigation system. On the other hand, open control loop systems apply a preset action, as is done with irrigation timers. [11]

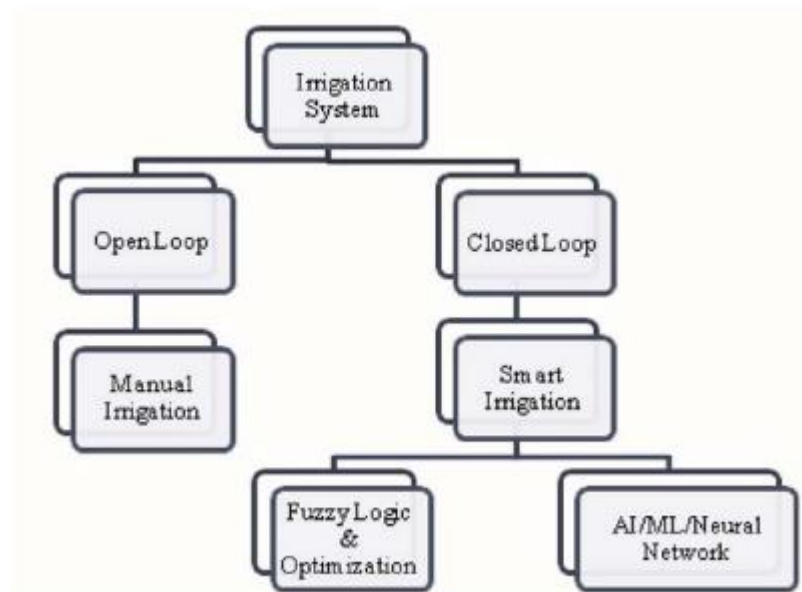


Figure I.11. Categorize of Irrigation System

X.1 Open Control Loop Systems

When using an open control loop system, a decision is made by the operator of water and the time at which this water should be applied. The operators then goes on to set an irrigation controller according the desired schedule .Open loop controllers are also constructed in such a way that a clock is used to start irrigation and the application of a given volume to stop irrigation. In this type of controller the parameters set by the system operator are how often and the volume of water to be applied.

Open loop control systems have the advantages that they are low cost, readily available, and many variations of the devices are manufactured with different degrees of flexibility related to the number of stations and schedule specification. However, they do not respond automatically to changing conditions in the environment and require frequent resetting to achieve high levels of irrigation efficiency. [13]

X.2 Closed Control Loop Systems

Closed loop controllers require data acquisition of environmental parameters, such as, soil-moisture, temperature, and relative humidity. The state of the system (for example measured soil-moisture using a sensor is compared against a desired state and a decision based on this comparison is made whether irrigation should be applied or not. Closed loop controllers for irrigation systems base their irrigation decisions on:

- 1) Direct measurement of soil-moisture using sensors.
- 2) Calculations of water used by the plants based on climatic parameters.
- 3) Both soil moisture sensors and climatic parameter measurements.

When using a computer-based controller, a very important component of a closed loop control system is the logic that is used to make decisions about operation of the irrigation system. Some of these systems may be very elaborate and use complicated simulation models that are verified with soil moisture measurements to arrive at an irrigation decision and implement the action at the appropriate time. Systems of this type (with different levels of complexity), are quickly being developed. [13]

XI. Sensors

A sensor is a device placed in the system that produces an electrical signal directly related to the parameter that is to be measured and in my project I need three types of sensors. [13]

Soil moisture sensor: The soil moisture sensor is used to measure the volumetric water content of soil. A moisture sensor is used to sense the level of moisture content present in irrigation field. It has a level detection module in which we can set a reference value. The results can range from 0% to 100%, where 100% represents fully saturated soil and 0% represents severely dry soil. For most crops, a soil's ideal moisture content ranges from 50% to 70%. [14]

Temperature Sensor: The temperature sensors are necessary to reduce the watering times when the weather gets cooler and less water is needed. Then as the weather begins to warm up, to add more watering time. The sensors monitor the ambient temperature in either Celsius or Fahrenheit. Depending on the sensor's specs, most crops do best at a temperature of 20°C to 30°C (68°F to 86°F).[14]

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Humidity Sensor: Used to monitor ambient humidity to help determine if irrigation is needed and how to adjust the amount of irrigation. It use calculate the environment's % relative humidity. The results can vary from 0% to 100%, where 100% represents totally saturated air and 0% represents excessively dry air. For most crops, a humidity level between 40% and 70% is ideal. [14]

XII. Cloud technology

Cloud and traditional databases could be considered two of the most important and widely utilized storage systems. Because they make it possible to store and retrieve important information when needed, Such storage solutions have facilitated the emergence of the big data idea, which describe vast amounts of datasets given the use of cloud computing in agriculture, particularly in irrigation-based systems, sensors are used to collect and process data. Further deductions from several researches have shown that the data is processed within the cloud, and users can access the data by establishing a connection with the cloud. Taking irrigation into account, cloud computing has also been utilized to create alerts by using algorithms. [15]

XIII. State of art technology

State-of-the-art technology or “leading-edge technology” means up-to-date technology reflected in equipment or procedures that, when applied at a major facility, will result in a significant reduction in the probability of a discharge. The technology represents advancement in reduction of leaks or discharges and shall have been demonstrated at a similar facility to be reliable in commercial operation or in a pilot operation on a scale large. The technology shall be in the public domain at reasonable cost commensurate with the reduction in probability of leaks or discharges achieved. [16]

XIV. Role of state of art in smart irrigation

The smart irrigation, utilizing state-of-the-art technology like Internet-integrated systems, plays a pivotal role in collecting precise data (such as temperature, humidity, and soil moisture); this helps in demonstrating its effectiveness in practical applications, and facilitating remote control. [17]

XV. Artificial Intelligence (AI) and Machine Learning

AI is a machine's ability to learn and implement tasks similar to those of a human brain, and it is powered by computers. When applied to a certain problem domain, AI algorithms can mimic human decision-making [18]. Irrigation systems have been integrated with AI and machine learning (ML) for adaptive decision-making.

XVI. Model Predictive Irrigation Systems

Development in smart agriculture through internet usage and increasing computational power facilitated large data collection from agricultural systems. The model predictive system has been employed in irrigation scheduling, irrigation canal control, soil moisture, and stem water potential regulation. [19]

XVII. Variable-Rate Irrigation (VRI)

VRI is a method of applying irrigation at variable rates in different irrigation management zones over the entire field in an optimized way. Normally, the application of irrigation water is uniform in the entire field. However, owing to soil spatial variability in soil topography, hydraulic properties and vegetation condition, the soil moisture content remains no uniform. When such soil spatial variability becomes significant, the field is split into different management zones consisting of those field areas with the same soil properties and crop conditions. Then, irrigation is applied at differential rates in different management zones. Such variable irrigation management may enhance the economic value of irrigation by improving WUE, increasing productivity and reduction in nutrient leaching. [19]

XVIII. Related Studies

In this section, we present a review of the relevant on irrigation systems. Each of them has focused on various aspects of the irrigation task. As illustrated in Table 1, we categorize the studies based on the following criteria [20]:

- Sensors use help irrigation systems achieve more accurate and smarter management, improve water use efficiency.
- Underground Sensor (soil depth): Shows the depth of testing for each sensor and whether it is partially or completely buried underground for real-time monitoring.
- Environmental sensing: it is used to monitor important weather pattern changes in real-time.[20]
- Soil texture class: Demonstrates testing of sensors based on soil texture, classified (Sandy loam, clay soil, soil (Entisol Orthent and OxisolUstox)).
- Machine learning shows whether a study is considered as machinelearning methods for intrusion detection systems, which in turn monitor network traffic.
- Deep learning approaches: it specifies if the study was focused on deep learning approaches for intrusion detection systems.[20]
- Low cost: it is not an essential matter in agricultural intelligence, and this depends on the type of sensor used and the system.
- Higher efficiency is important to increase irrigation efficiency and improving sustainability.
- Anomaly detection: the detection of anomalies is a crucial stage that will enhance the quality of results in predictive modeling and pattern extraction, enabling the identification of problems and facilitating decision making in data-based services.[20]
- Geographic information systems (GIS): provide a potent instrument for near-real-time analysis of crop status. Ground-based equipment, aerial drones, and satellites all collect GIS agriculture data.[20]

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Ref	Sensors	Underground sensing(soil depth)	Environmental sensing	Soil texture class	ML	DL	Low cost	higher efficiency	Anomaly detection	GIS
[21]	tensiometers and Watermarks	20cm, 30cm, 60cm	Yes	Sandy loam	Yes	No	No	No	Yes	No
[22]	DPHC(dual-probe heat-capacity)	Yes	Yes	No	No	No	yes	Yes	No	yes
[23]	Capacitive	6 cm	Yes	clay soil	No	No	yes	Yes	No	No
[24]	M413 sensor and MP sensor	20 cm,40cm	Yes	clay soil	Yes	No	yes	Yes	No	No
[25]	NPK	Yes	Yes	NO	Yes	No	No	Yes	No	yes
[26]	Tensiometers	15cm 45cm 75cm	Yes	clay soil	Yes	No	No	Yes	No	No
[27]	YL-69 sensor and ECH2O sensor	0 to 0.40 m	Yes	soil (Entisol Orthent and OxisolU stox)	Yes	No	yes	No	Yes	No
[28]	NPK and Spark Fun Soil Moisture Sensor	Yes	Yes	Soil	Yes	yes	No	Yes	No	yes
[29]	Capacitive SoilMoisture Sensor V2.0	10cm 15 cm	Yes	Clay soil	No	No	No	Yes	No	yes
[30]	TDR sensor FDR sensor NP sensor	5 cm	No	Soil	Yes	yes	No	Yes	No	yes
PP	Capacitive sensor V2.0 Watermark	9 cm	No	Soil	Yes	No	yes	Yes	No	No

Table I.8 a comparative analysis between the previous platform and proposed platform.

Conclusion

Developments occurring in agriculture, specifically in irrigation, are important for the sustainability of crop production without wasting or damaging them. Irrigation intelligence uses the IOT system (Internet of Things) and new technologies in the field of agriculture to reach the goal of precision agriculture. The system uses a sensor station that measures soil moisture, temperature and humidity and sends them to the control station to provide the appropriate irrigation water for each crop.

CHAPTER II:

Conception of the Proposed Platform

Chapter II: Conception of the proposed platform

Introduction

A smart irrigation system consists of software and hardware interconnected through different technologies, including artificial intelligence (AI) for example machine learning method using KNN algorithm and others.

This system mainly consists of the three sensors, i.e., a temperature and humidity sensor and two types of soil moisture sensors. Soil moisture sensors are used to measure the value of soil moisture, and temperature and humidity sensors are used to measure the temperature and humidity in the surrounding areas since it is one of the main factors controlling the nature of the soil. All these sensors are interfaced with Arduino Uno. With the help of wireless communications. And send this information to the Arduino mega2560 to control the valve to improve water use in irrigation while storing the information in a memory card connected to the Raspberry pi 3.

Chapter II: Conception of the proposed platform

I. The hardware architecture of the platform

The basic platform in this project is smart agriculture with low cost to enhance the efficiency of irrigation for agriculture, it allows the deployment of a number of highly efficient sensors to monitor soil moisture and environmental factors (temperature and humidity) that affect the soil and the crop, implementing the concept of “smart irrigation”. To provide highly creative, easy-to-implement and convenient methods, it uses technologies like AI to predict what is most important Environmental factors for a variety of crops, for soil texture on a given farm, and at a given moment. Our platform hardware consists of two parts: The first part is sensor control and data transfer to the second part, which is the control source for the crop irrigation system.

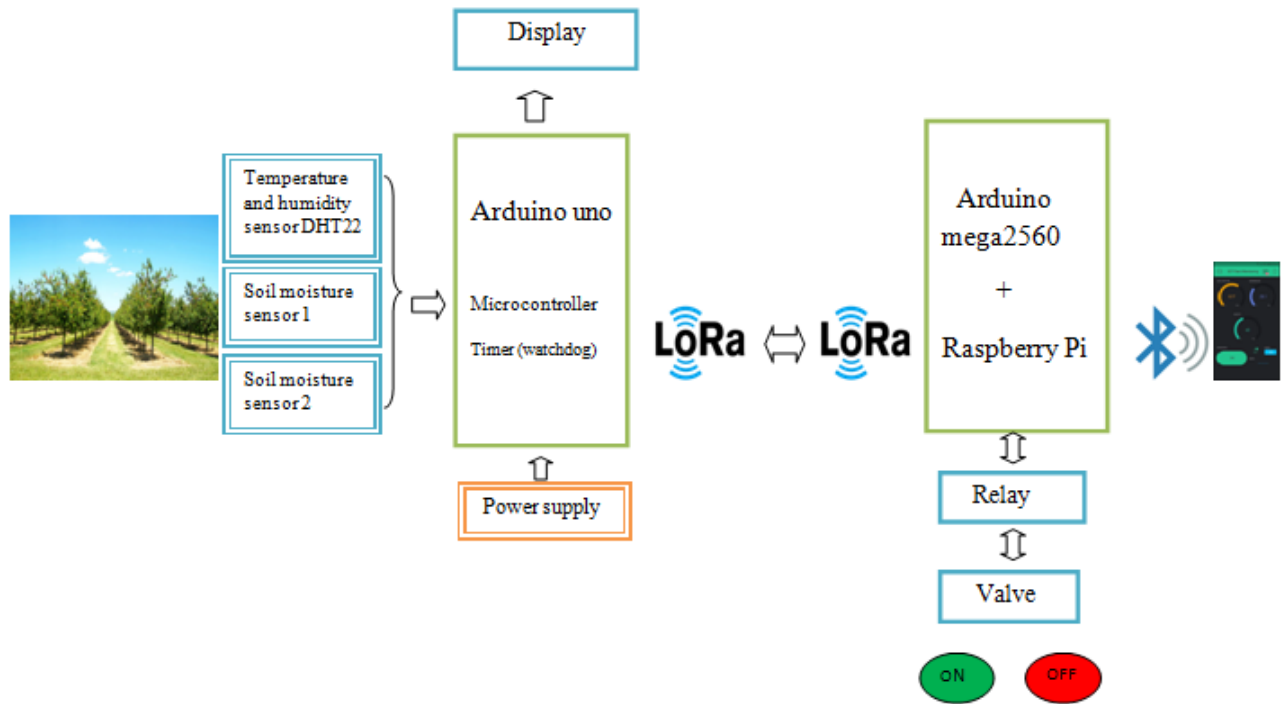


Figure II.1. Irrigation in precision agriculture

II. The software architecture of the platform

This architecture enables the smart irrigation platform to collect, analyze, and act upon data in real-time, helping farmers make informed decisions to optimize water usage, improve crop yield, and reduce environmental impact. Additionally, it allows for scalability, flexibility, and interoperability with other agricultural technologies and services.

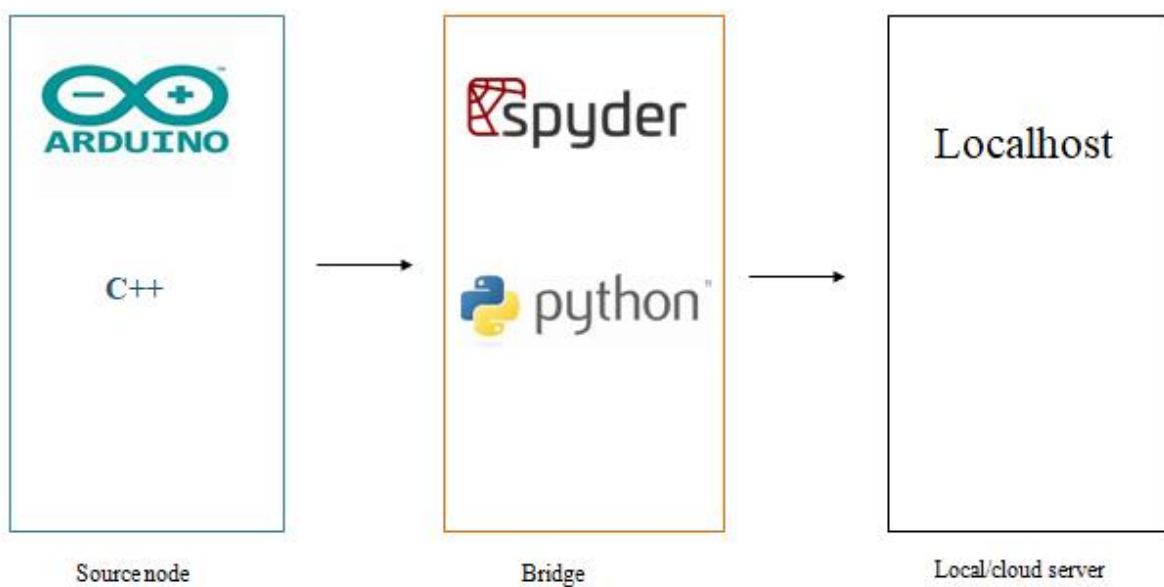


Figure II.2. The software architecture of the platform

III. Smart monitoring unit design (hardware and software description)

The sensor is connected to smart monitoring module which mainly consists of two parts. First part consists of a group of sensors : capacitive soil moistureV2.0 sensor, watermark sensor and air temperature and humidity sensor(DHT22), which have been used to monitor various environments parameters so that the collected data is sent directly to arduino uno. The microcontroller is responsible for controlling these sensors and is linked to the solar panel and battery that operates the system. The arduino also sends information via Lora to the second controller, connected to arduino mega2560(the raspberry pi), which in turn is responsible for opening the valve in a smart way that is applying a specific time to turn it on and off.

III.1 Hardware (Components)

III.1.1 Source node

The following table summarizes details about the sensors that are included in it.

Components	Description
Capacitive soilmoistureV2.0 sensor	This sensor is used to measure soil moisture. It reduces corrosion by sensing water capacitive rather than resistive, so water does not come into direct contact with the metal part of the sensor.
Watermark sensor	It is robust, easy to use, maintenance-free and frost-resistant. It measures changes in soil moisture to avoid excess water and the accompanying risk of crop suffocation. It also prevents water shortages, which are fatal for production, and allows you to reduce your costs and save water.
DHT22 sensor	A capacitive humidity sensor and a thermistor to measure the temperature and humidity of the air, and transmit it digitally on a serial bus.
Oled display	An OLED (Organic Light-Emitting Diode) display is the best of the electronics for displaying due to their vibrant colors, high contrast ratios, and low power consumption.

Table II.1. Hardware components included in the source node

Chapter II: Conception of the proposed platform

III.1.1.1 Sensors:

The main integral components for the system can be considered to be the sensors. They are the only medium through which live data gets transmitted from the field for further processing. Thus; the following sensors are being used for the required data.

Capacitive soil moisture sensor V2.0: this soil moisture sensor measures soil moisture levels by capacitive sensing, capacitance is varied on the basis of water content present in the soil. The capacitance is converted into voltage level basically 3.3v or 5v. It is made of corrosion-resistant material which gives it excellent service life. [31]

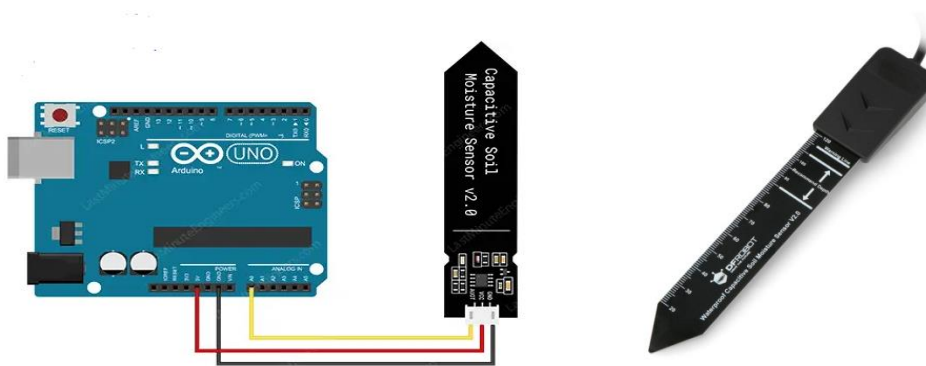


Figure II.3. Capacitive soilmoisture v2.0 sensor

Num	Label	Description
1	GND	Power GND(0v)
2	VCC	Power VCC(3.3~5.5)
3	Aout	Analog Signal Output(0~2.3)

Chapter II: Conception of the proposed platform

Basic source code/program

Here is simple source code for interfacing capacitive soil moisture sensor with arduino uno.

A screenshot of the Arduino IDE 2.3.2 interface. The title bar reads 'capacitivesensor | Arduino IDE 2.3.2'. The menu bar includes 'File', 'Edit', 'Sketch', 'Tools', and 'Help'. The toolbar shows icons for checking, running, and uploading code, along with a dropdown menu currently set to 'Arduino Uno'. The main editor window displays a file named 'capacitivesensor.ino' with the following C++ code:

```
1  #define AOUT_PIN A0 // Arduino pin that connects to AOUT pin of moisture sensor
2  const int dry=595;
3  const int wet=239;
4
5  void setup() {
6    Serial.begin(9600);
7  }
8
9  void loop() {
10   int sensorvalue = analogRead(AOUT_PIN); // read the analog value from sensor
11   //sensor has a rang of 239 to 595
12   //we want to translate this to a scale or 0% to 100%
13   int percentagehumidity=map(sensorvalue,wet,dry,100,0);
14
15   Serial.print("Capacitive moisture sensor: ");
16   Serial.println(percentagehumidity);
17   Serial.println("%");
18
19   delay(500);
20 }
21
```

Figure II.4. Code for capacitive soil moisture sensor in arduino IDE software

Advantages and disadvantages of capacitive soil moisture sensor

Advantages	Disadvantages
• Lower interference from ions • Simple, easy to interface with arduino • High sensitivity • Low noise • Low response time	• Can only be used to measure moisture

Table II.2.Advantages and disadvantages of capacitive soil moisture sensor

Chapter II: Conception of the proposed platform

Watermark sensor: is an electrical sensing device that is buried in the active root zone to measure soil water tension. The sensor consists of corrosion resistant electrodes embedded within a specialized granular matrix. Water in the soil exchanges with the sensor matrix, providing a measurement of centibars (or kPa) of soil water tension. [32]



Figure II.5. Watermark sensor

Basic source code/program

Here is simple source code for interfacing watermark sensor with arduino uno.

```
watermark1 | Arduino IDE 2.3.2
File Edit Sketch Tools Help
Arduino Uno
watermark1.ino
1 void setup() {
2   Serial.begin(9600);
3 }
4 void loop() {
5   float v_in = 3.26;
6   float pin_scale = 1023.0;
7   float res = 22000.0;
8
9   digitalWrite(6, HIGH); //MY POWER PIN
10  digitalWrite(7, LOW); //MY GND
11  delay(1000);
12  float val = analogRead(A6);
13
14  digitalWrite(6, LOW);
15  digitalWrite(7, LOW);
16
17  float v_out = val*(v_in/pin_scale);
18
19  float rwm = res*((v_in-v_out)/v_out);
20
21  float cb=0.0;
22  float soil_temperature = 22.0;
23
24  if (rwm > 0 && rwm <= 1000) {
25    cb = 20 * ((rwm / 1000) * (1 + 0.018 * (soil_temperature - 24)) - 0.55);
26  }
27  // Serial.println(rwm);
28  // Serial.println(cb);
29  // delay(1000);
30 }
```

Figure II.6. Code for watermark sensor in arduino IDE software

Chapter II: Conception of the proposed platform

Advantages and disadvantages of watermark sensor

Advantages	Disadvantages
• Good accuracy in medium to fine soils due to their fine-sized particle similar to its inner granular matrix. • Easy handling (light weight, pocket-size, easy installation and direct reading). • Larger moisture reading range (0 to 200cb, or kPa). • Usable over several seasons with proper care. • Continuous measurements at same location.	• Slow response to changes in soil water content, rainfall or irrigation (minimum 24 hours). • Lack of accuracy in sandy soil due to their large particles. • Need for each soil type to be calibrated

Table II.3. Advantages and disadvantages of watermark sensor

DHT22 sensor: is a basic sensor that is used to measure the temperature and humidity in the surrounding air. It's known for its low power consumption [33]

Temperature measuring range -40°C to 80°C

Temperature Accuracy $\pm 0.5\%$

Humidity measuring range 0% to 100%

Humidity Accuracy $\pm 2\%$

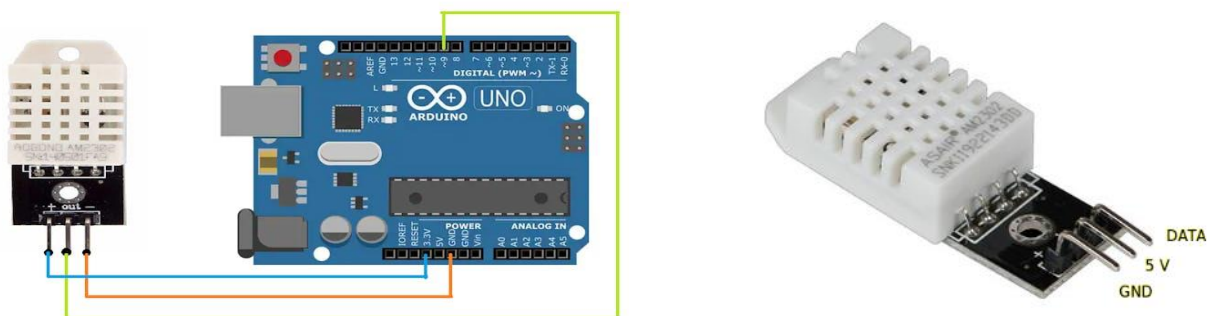


Figure II.7.DHT22 sensor

Chapter II: Conception of the proposed platform

Num	Label	Description
1	GND	Power GND(0v)
2	VCC	Power VCC(5V)
3	DATA	Outputs both Temperature and Humidity through serial Data

Basic source code/program

Here is simple source code for interfacing DHT22 sensor with arduino uno.



```
dht22 | Arduino IDE 2.3.2
File Edit Sketch Tools Help
Arduino Uno
dht22.ino
3 // Capteur de temperature et d'humidite DHT22
4 #include "DHT.h"
5 // Definit la broche de l'Arduino sur laquelle la
6
7 // broche DATA du capteur est reliee
8 #define DHTPIN 2
9 // Definit le type de capteur utilise
10 #define DHTTYPE DHT22
11 // Constante mesuree avec un thermometre de reference
12 // qui sert a etalonner le capteur de temperature
13 #define DELTA_TEMPERATURE 0.7
14 // Declare un objet de type DHT
15 // Il faut passer en parametre du constructeur
16 // de l'objet la broche et le type de capteur
17 DHT dht(DHTPIN, DHTTYPE);
18 float temperature=0.0;
19 float humidity=0.0;
20 void setup() {
21   Serial.begin(9600);
22 }
23 void loop() {
24   // Recupere la temperature et l'humidite du capteur et l'affiche
25   // sur le moniteur serie
26   Serial.println("Temperature = " + String(dht.readTemperature() - DELTA_TEMPERATURE)+" °C");
27   Serial.println("Humidite = " + String(dht.readHumidity())+" %");
28   // Attend 10 secondes avant de reboucler
29   delay(1000);
30 }
```

Figure II.8. Code for DHT22 sensor in arduino IDE software

Advantages and disadvantages of DHT22sensor

Advantages	Disadvantages
• Very quick response. • high-cost performance • high anti-interference ability	• it can only get new data from it once every 2 seconds

Table II.4. Advantages and disadvantages of DHT22sensor

Chapter II: Conception of the proposed platform

Arduino Uno: Arduino is open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. Arduino Uno shown in the Fig. 4 can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators. An Arduino microcontroller is also preprogrammed with a boot loader that simplifies uploading of programs to the on-chip flash memory, compared with other devices that typically need an external programmer. The Arduino Uno is a microcontroller board based on the ATmega328. [34]



Figure II.9. Arduino Uno

LORA (short for Long-Range): is a spread spectrum modulation technique derived from chirp spread spectrum (CSS) technology. The data will be hashed with high frequency pulses to produce a signal with a higher frequency range than the original data frequency (this is called chipped). This high frequency signal is then further encoded by the chirp signal sequence, which is a time-varying sinusoidal signal before being transmitted to the antenna for sending. Lora is a good choice for an IOT solution that requires long data communication range while still using very little power. [35]

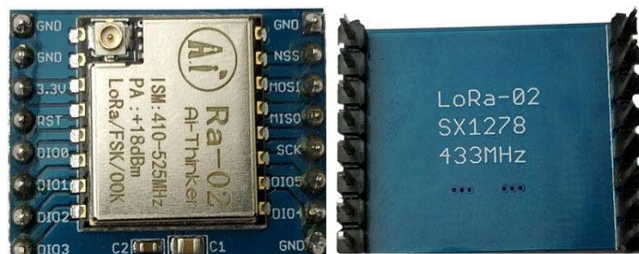


Figure II.10. LORA SX1278

Chapter II: Conception of the proposed platform

Resistors: this resistor limits current flow, modifies signal levels within the circuit. [36]



Figure II.11. Resistor

An OLED (Organic Light- Emitting Diode) display module that utilizes organic compounds to emit light when an electric current is applied. It showcases information like sensors readings, system statuses in a clear and energy-efficient manner. [37]



Figure II.12.OLED display

Relay module is an electrically operated switch. Relays are used where it is necessary to control a circuit by a separate low-power signal. A relay with calibrated operating characteristics and sometimes multiple operating coils are used to protect electrical circuits from overload. Raspberry pi is connected to the devices via relay. Here relay can be operated as switch to on or off the devices. [38]



Figure II.13.relay module

Chapter II: Conception of the proposed platform

Water Flow Sensor—FS300A G3/4 Inch

The FS300A consists of a water rotor, a hall-effect sensor, and a plastic valve body, as shown in **Figure 14**. The water flows in through the inlet and out through the outlet due to the flow of water and the wheel rolls, and so does the magnet. The rotation of the magnet triggers the hall-effect sensor, which outputs high- and low-square waves. We calculate the water flow by counting the square waves [39].



Figure II.14.FS300A G3/4 inch water flow sensor

Valve is an electro mechanically functioned valve, which is measured by an electric current through a solenoid. It can be used to regulate the water flow and to measure the level of water. Solenoid valve offers fast and harmless switching; more reliability, and lengthy service life, best medium compatibility of the materials used short control power and compressed design. [40]



Figure II.15.Valve

Chapter II: Conception of the proposed platform

I.1.2Power Supply:

Solar panel: The component for main power supply is solar panel. This transmits the solar energy into electrical energy for the system. With the help of this renewable source of energy. We have not only eliminated the factor of constant electrical power supply, but have also helped in lowering the economical effect of the system .the power is formed and stored in a cell attached to the system and then is used according to the need of other components.[41]



Figure II.16. Solar panel

The Lithium Battery Charger PCB is an essential component for fast and efficient charging of lithium-ion batteries in various applications. This high-quality PCB board is designed to optimize the performance of lithium-ion batteries while ensuring maximum safety during charging. [42]



Figure II.17. Lithium Battery Charger PCB Circuit Board

The lithium battery is a type of battery used for low-power, high-reliability, and long-life applications. It uses in power supply to stock energy and use tonight. [43]



Figure II.18. The lithium battery

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III.2 Software:

III.2.1 Machine learning:

(ML) is a branch of artificial intelligence (AI), computer science and an evolving branch of computational algorithms that are designed to emulate human intelligence by learning from the surrounding environment. They are considered the working horse in the new era of the so-called big data. Techniques based on machine learning have been applied successfully in diverse fields ranging from pattern recognition, computer vision, spacecraft engineering, finance, entertainment, and computational biology to agriculture. [44]

There are various algorithms that do predictions based on supervised learning, they are: Linear and Logistic Regression, Decision tree, Support Vector machine (SVM), K-Nearest Neighbor (KNN).

Among these classification methods KNN classification has many advantages, they are:

- Robust with regard to the search space, don't have to be linearly separable.
- Classifier can be updated online at minimal cost as new instances with known classes are presented.
- Few parameters to tune: distance metric and k.
- Faster than other classification methods.

Hence we are incorporating KNN classification method (that calculates distance of neighbors using Euclidean distance formula) to build our system. [45]

III.2.2 KNN CLASSIFIER

K-Nearest Neighbor is one of the Machine Learning algorithms based on Supervised Learning technique. The main idea behind the algorithm is that the elements that are close to each other would belong to the same category. [45]

How it works:

Chapter III: Conception of the proposed platform

The K-Nearest Neighbors algorithm uses the entire data set as the training set. When an outcome is required for a new data instance, the KNN algorithm goes through the entire data set to find the nearest instances to the new instance, or the k number of instances most similar to the new record, and then outputs the mode (most frequent class) for a classification problem. The value of k is user specified. The similarity between instances is calculated using measures such as Euclidean distance. [45]

Anaconda is free software that provides you with a toolkit that is tailored for research and science. Installing Anaconda gives you access to different environments that allow you to code in either Python or R. [46]

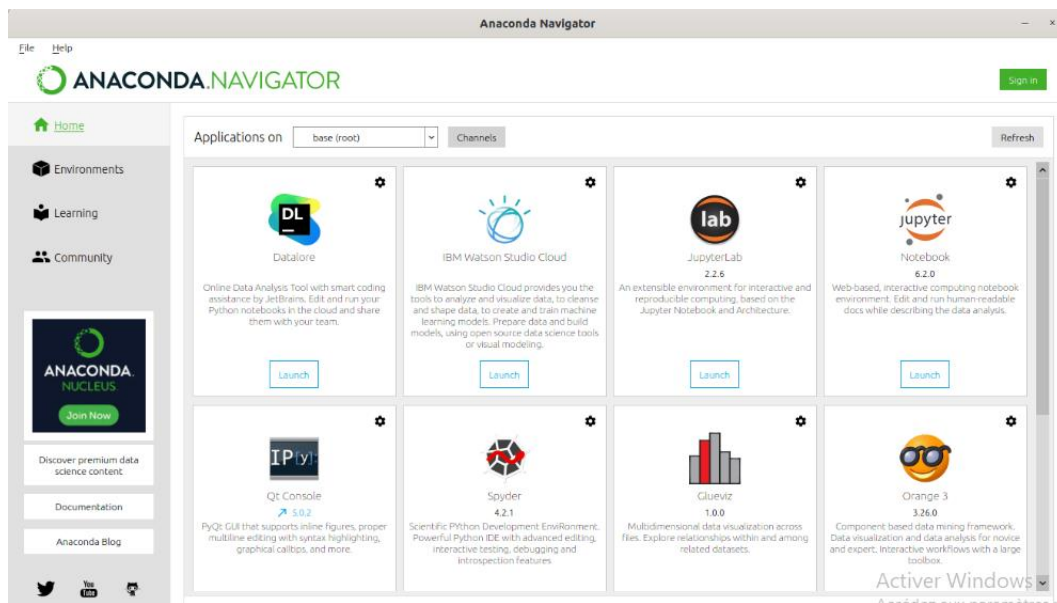


Figure II.19. Interface of Anaconda Navigator

Jupyter Notebook (jupyter.org) is a powerful, open-source, browser-based tool for interactive development and presentation of data science projects. Each notebook consists of a collection of executable cells, and each cell contains either text formatted using the Markdown language or executable code (usually Python or R). When a 'code cell' is executed any graphical or text output (numerical results, figures or tables) is presented within the document immediately below the cell to get started with Jupyter Notebooks must be install the Anaconda distribution (anaconda.com), for which graphical installers are available on Windows, macOS and Linux operating systems.

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After installation a local Jupyter server can be launched using the Anaconda-Navigator application. To run a specific local Jupyter notebook with Anaconda-Navigator the user can navigate to the appropriate local folder using the browser-based interface, and click on the desired notebook file. [47]

Dataset: Automated irrigation systems are emerging methods for irrigation crops with the required amount of water, which conserves water wastage and avoids over irrigating crops. To train the automated irrigation method, we require the data set for better decision-making and controlling the irrigation system. The data set is collected from various sensors, for example, capacitive soil moisture sensors and DHT-22 sensors. These data sets can be used to analyze and make decisions about controlling the automated irrigation system. Soil moisture, air temperature, and humidity are measured, and based on the soil moisture; the water motor's on/off status can be controlled. [48]

Soil Moisture	Temperature	Air Humidity	Pump Data
683.802906	29.1849079	71.7896995	0
408.571567	33.7072047	77.9773905	1
659.092074	24.7603111	60.7762821	1
842.929764	32.7385151	59.3235435	0
414.19932	25.6927445	66.6249141	1
487.521226	33.8068093	47.7746925	1
820.856733	32.6594951	40.317592	0
726.504807	38.0839395	50.9159505	0
939.915978	35.4307471	60.8227213	0
628.397718	34.2329232	42.9944024	1
780.389548	32.4514008	72.2822254	0
768.701079	22.611857	62.2145914	0
468.513799	27.0102486	61.7792157	1
801.647577	24.7470515	64.8623258	0
651.945474	24.0185616	56.5716656	1
685.823752	32.9637588	64.836761	0
552.4985	27.9982787	62.0580009	1
527.58805	27.8969826	49.9239028	1
762.576033	34.8367316	45.7287947	0
440.630396	22.4662202	40.2352898	1
748.594545	32.3718672	50.5112164	0
541.462498	23.0142661	67.3192115	1

Figure II.20. Dataset to control irrigation

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III.2.3 Application KNN (K-Nearest Neighbors)

Implementing the K-Nearest Neighbors (KNN) algorithm in a smart irrigation system can be quite effective for making decisions based on past data. By applying RMSE, MSE and MAE in the context of a smart irrigation system with the KNN algorithm.

It can effectively assess and enhance the system's ability to make accurate predictions regarding irrigation needs, thereby optimizing water usage and promoting efficient irrigation practices.

I ran tests on randomly obtained sample data from about 3,000 cases. These cases are provided to train the KNN model on the proposed prediction system. That is, accuracy and recall. K must be chosen precisely (for example, you get $K = 2$ with Maximum accuracy: 0.99666).

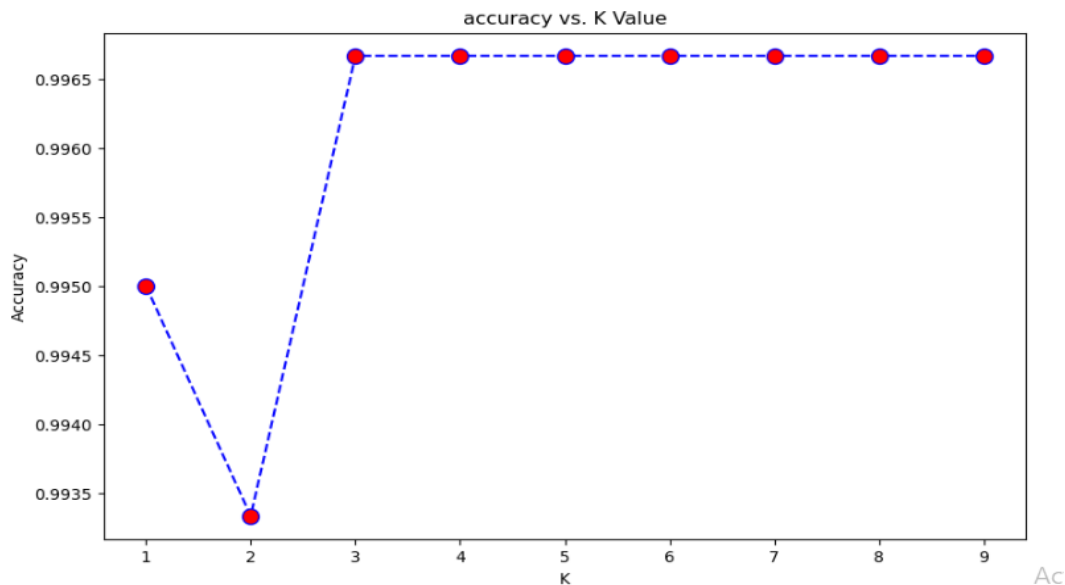


Figure II.21.for chosen K with best accuracy

By adjusting the values of the training data and adjusting the value of “K”, we can obtain a better model of the system. Accuracy of model at $K=2$ is 0.99333.

Compare between KNN and Logistic Regression, RandomForestClassifier:

Comparing the k-Nearest Neighbors (KNN) algorithm with random forest and Logistic Regression in terms of accuracy can vary depending on the dataset. While Logistic Regression can achieve high accuracy in certain scenarios, it's essential to carefully consider its strengths and limitations compared to

Chapter II: Conception of the proposed platform

random forests and KNN to choose the most suitable approach for a particular problem. Conducting empirical evaluations specific dataset is often the best way to determine which algorithm performs best in terms of accuracy.

Algorithms	Accuracy
K-Nearest Neighbors (KNN)	0.9933
Logistic Regression	0.9983
Random Forest	0.995

TableII.5. Comparison accuracy of soil moisture between logistic regression and others algorithms

Classification Report for k-Nearest Neighbors (KNN):

	precision	recall	f1-score	support
0	0.99	1.00	0.99	298
1	1.00	0.99	0.99	302
accuracy			0.99	600
macro avg	0.99	0.99	0.99	600
weighted avg	0.99	0.99	0.99	600

Classification Report for Logistic Regression:

	precision	recall	f1-score	support
0	0.99	1.00	0.99	298
1	1.00	0.99	1.00	302
accuracy			0.99	600
macro avg	0.99	1.00	0.99	600
weighted avg	1.00	0.99	1.00	600

Classification

Random Forest:

Report for

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Arduino IDE is open source software that is mainly used for writing and compiling the code into the arduino module. We can download the Software from Arduino main website. As I said earlier, the software is available for common operating systems like Linux, Windows, and MACOS; we select to download the correct software version that is easily compatible with our operating system. [49]

Arduino IDE is used to program the microcontroller that controls the timer with watchdog timer when enabled through programming languages will result in lower power consumption. [50]

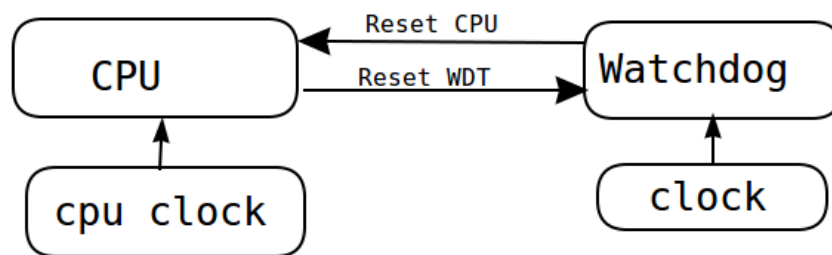
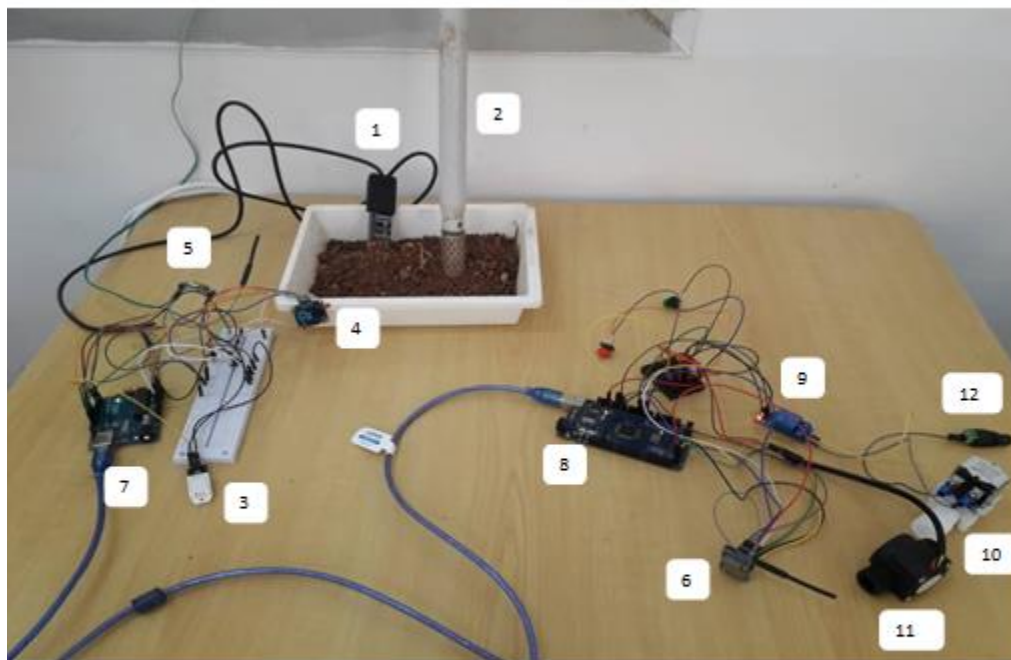


Figure II.22. Diagram Watchdog Reset Flag Register (WDRF)

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Results:

Using an Arduino Uno and Mega2560, paired with two LoRa R02 modules, a capacitive soil moisture sensor, a Watermark sensor, a DHT22 sensor, a valve, a water flow sensor, and a relay module, creates an effective smart irrigation system. The Arduino Uno controls field sensors and actuators, while the Mega2560 manages overall system operations and communication. LoRa modules enable long-range wireless data transfer. The sensors monitor soil moisture, temperature, and humidity, optimizing water use and plant health. Actuators and the relay module control water flow precisely. This system allows for remote monitoring, data analysis, redundancy, and scalability, resulting in efficient, cost-effective, and reliable irrigation management. Proper sensor calibration, power management, data integrity, and system integration are crucial for successful implementation.



- | | | |
|---|---------------------|-----------------|
| 1. Capacitive Soil Moisture Sensor V2.0 | 2. Watermark Sensor | 3. DHT22 Sensor |
| 4. OLED Display | 5/6. LORA R02 | 7. Arduino Uno |
| 8. Arduino mega2560 | 9. Relay Module | 10. Valve |
| 11. Water Flow Sensor | 12. Power | |

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DesignPCB Card

Designed two shields in easy eda software

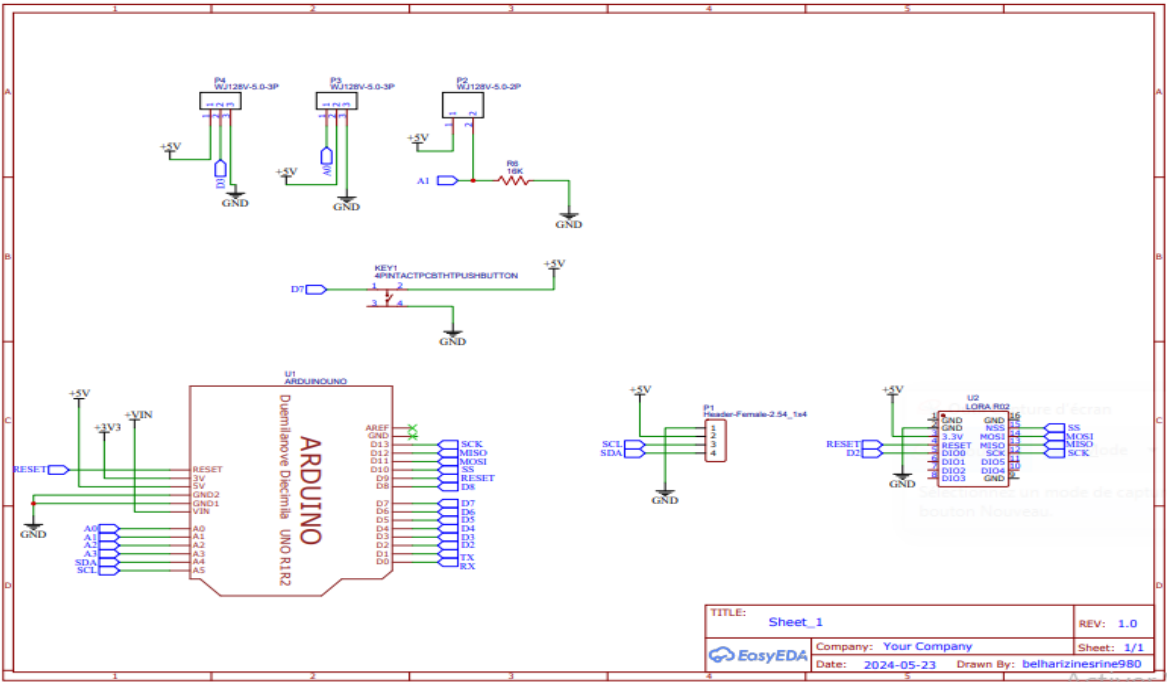


Figure II.23. Design Arduino Uno Shield in Easy EDA

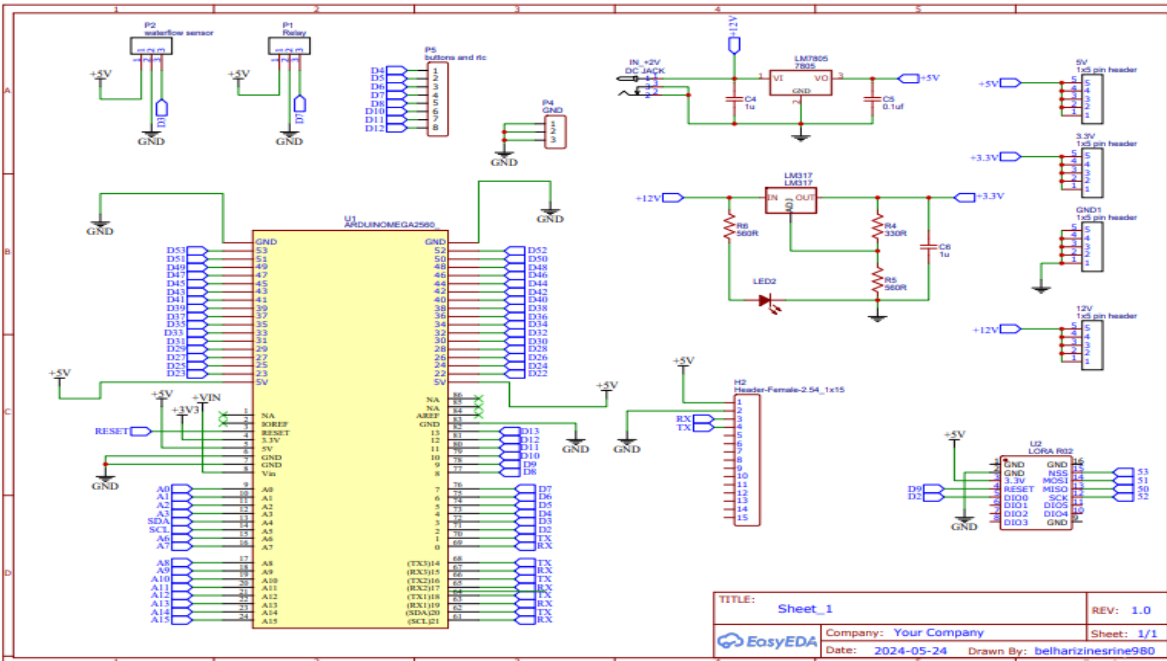


Figure II.24. Design Arduino Mega2560 Sheild in Easy EDA

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Fusion 360, a product introduced by Autodesk and integrating industrial design, structural design, mechanical simulation, and CAM, turns out a design platform supporting collaboration and sharing both cross-platform and via the cloud. Fusion360 comprises several working environments and modules: modeling, molding, surface patching, rendering, animation, simulation, CAM, drawings and so on [51].

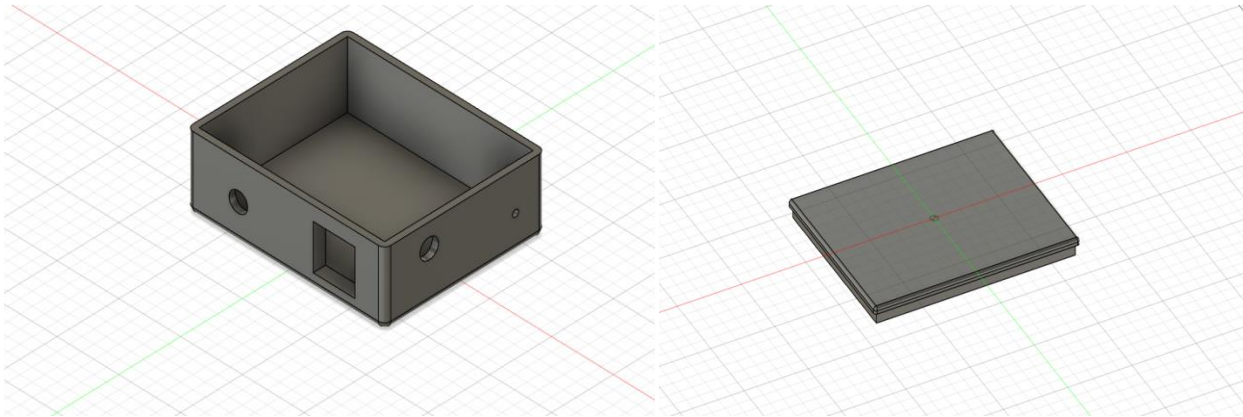


Figure II.25. Box model in Autodesk Fusion 360

Future works

Irrigation system is very important in the economy of our country, so I will seek to develop my project by providing more advanced methods such as adding the satellite can be used to control it at a very large distance using a GSM module, and the latter is one of the most accurate methods for obtaining information about the crop. While being somewhere else.

Conclusion

Smart irrigation systems, empowered by advancements in sensor technology, data analytics, and machine learning algorithms like K-Nearest Neighbors (KNN), offer a transformative solution to the age-old challenge of efficient water management in agriculture. By integrating real-time sensor data with predictive models, these systems enable precise and targeted irrigation, tailored to the specific needs of crops and the environment.

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irrigation

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I. Project presentation

I.1 The project idea

Agriculture is the second largest economic source after oil in Algeria. In recent years, the country has been seeking to provide the needs of farmers. However, the basic factor for agriculture, which is irrigation, has become a major problem for these farmers with the lack of rain during this period or it's falling at the wrong time. Despite this, the farmers sought to solve this problem, we provide drilling wells or building basins, especially for collecting water, etc., as it made some farmers disorganized in watering the crops. From here, I took the idea of my project, which is one of my contributions to preserving the crops during their growth period by providing them with the percentage of water according to their need in a smart way with preserving water resources at a lower cost.

I.2 Suggested values

I.2.1 Short time and high performance

Usually, the smart watering product is manufactured and sold within a period of one to two months in international companies, but our product will provide a shorter period of time to provide a service or even sell it to our customers, approximately 20 days when sold and one to two days in the case of service, according to their request.

I.2.2 Widely accessible price

The current prices of the smart irrigation product range between 20,000 and 90,000 DZD. Our product, which has no direct competitors in the Algerian market, will be offered to our customers at a price of 8,000 DZD for those who want to provide a service to them, and for those who want the product, we will offer it at a price of 82440.00DZD.

I.2.3 Determine a product type

To make irrigation smarter, and more accurate, our product seeks to maintain crop production while preserving water wealth and keeping pace with modern developments.

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I.3 Work team

First and last name: Belharizi Nesrine

Specialty: Instrumentation and metrology

Project: Smart irrigation

Economic sector: industrial

Place of planting: Ain timouchent

Surface : 150 m²

Farmedby:

- Chreit Mohamed Amine
- Dahane Mohamed Amine

I.4 Project goals

Our goal is for SI to become a leader in the production of smart watering machines in Algeria and meet the overall national demand in the medium term. In the absence of direct national competitors, we have access to more than 25% of the Algerian market share in the first few years.

I.5 Timeline for project completion

I.5.1 Initial project studies (2 to 3 months)

- Identify target customers.
- Conducting interviews with farmers, collecting existing data regarding the market, and conducting studies to reach an idea.
- Measuring the competition in the market and the shares it occupies.

I.5.2 Launching the activity (3 months)

- Purchase of raw materials.
- Planning the production methodology with research.

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- Then he started making the product

I.5.3 Completion of the product (10 days)

- Choosing the design and form of packaging.

II. Innovative aspects

II.1 The nature of innovations

This project has the reputation of being a market innovation and a technological innovation:

II.1.1 Market innovation

My project is one of the best competitive innovations in the Algerian market that contributes to the development of the agricultural field that our country has been seeking in recent years.

II.1.2 Technological innovation

This project facilitates the farmer's life. As the largest contributor to preserving water resources first and crops second, with a lower cost.

II.2 Areas of innovation

This is the only project in Algeria that relies on the use of artificial intelligence to control crop irrigation according to the classification of soil condition (dry or wet) in an automatic manner.

III. Strategic analysis of the market

III.1 Market Sector

III.1.1 Target customers

Our product is intended for the following customers:

At present. Agricultural irrigation has become more precise compared to the past. So, excessive irrigation has cost farmers huge losses in terms of money and destroyed agricultural lands. With all these reasons, it is necessary to improve these damages, especially by developing irrigation in a smart way

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with a reasonable price. This helps the farmer as he is the first and only customer who deserves this product.

III.1.2 Target market

At the beginning of my production journey. I will target my state (Ain Temouchent state) as an agricultural region, and after that I will seek to spread to other states and even to other countries in Africa.

III.2 Measuring the intensity of competition

There is no direct competitor in Algeria that guarantees the production and sale of smart watering devices like mine, and I will be the first to offer this type of product, which makes marketing it much easier.

However, I cannot say that I do not have a competitor in the global market, considering China is my first competitor as a company (Shenzhen and (Unlock A Smart Irrigation Solution with AgTech)).

Comparison of the product with its competitors

Features	My business	Competitor1	Competitor2	Competitor3
Quality of product	Nice	excellent	excellent	Excellent
Pray	82440.00DA	97403.33 DA	Nan	32221.17 DA
Delivery time	20 days	1month or 2 month	1month	15 days
brand name	SI	QOTO	N	INKBIRD
Need/Customers	Farmers	Farmers	Farmers	Farmers
the types of market	Interior and Exterior	interior	Interior and exterior	Interior and Exterior

Table III.1.Comparison of the product with its 3 competitors Chinese

III.3 Marketing strategy

As for our marketing strategy, we will base it on:

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- Cooperation with the Agriculture Directorate: to provide service to customers (farmers)
- Deal with electronic companies such as Amazon. Alibaba / as the two best platforms for selling the product
- Trade fairs and seminars: They form an ideal platform to present a product to future buyers and potential customers regarding what we offer and, in fact, displaying the data accumulated during product development during scientific events can be used to establish the scientific credibility of our product.

IV. Production and organization plan

IV.1 Production process

The production process of our product takes place according to three main stages:

- Purchase and receipt of raw materials undergo automatic quality control upon arrival.
- Collect and program sensors following a fixed protocol.
- Packaging and labeling of the product

IV.2 Display

To purchase raw materials, I will deal with Algerian and even foreign suppliers who already have experience in the Algerian market.

IV.3 Work

Since I am at the beginning of the production path, I am thinking of creating at least 4 direct jobs (executive manager, 1 programmer, 2 electronics specialist workers, 1 designers of the final product.

IV.4 Key Partners

Suppliers are considered the pillar of the company's success. When building a partnership with the best suppliers, this may be considered a key to productive success. Among these suppliers there are international ones, such as Amazon or Alibaba, and local ones, such as Arduino1001, and even stores from Oran and Mostaganem.

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VI. Financial plan

VI.1 Cost and charges

VI.1.1 Charges variables

	Gross product	Overall quantity	Unit	Gross product value (DA)	Unit quantity (for 1 unit)	Unit	Unit costprice (DA)
Raw material	Arduino	1		1000.00	2		2000.00
	Raspberry pi	1		11800.00	1		11800.00
	DHT22 sensor	1		1570.00	1		1570.00
	Capacitive soil moisture sensor	1		2200.00	1		2200.00
	Watermark sensor	1		36900.00	1		36900.00
	Lora R02	1		8400.00	2		16800.00
	Oled display	1		2300.00	1		2300.00
	Valve	1		3200.00	1		3200.00
	Water flow sensor	1		850.00	1		850.00
	RTC timer	1		2920.00	1		2920.00
	PCB	1			2		0.00
	Solar panel	1		600.00	1		600.00
	Battery	1		100.00	1		100.00
	lithium battery charge	1		1200.00	1		1200.00
Total variable expenses				73040.00	///		82440.00

Table III.2. Charges variables

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VI.1.2 Fixed variables

Organization/Workforce	Job	Number	Monthly Salary (DA/Year)	Gross Salary (DA/Year)
	executive manager	1	50000	600000
	Programmers	1	50000	600000
	electronics specialist workers	2	55000	1320000
	designers of the final product	1	50000	600000
	Housemaid	1	10000	120000
	Total payroll	6	215000	3240000

Miscellaneous Fees and Services	Miscellaneous Fees and Services	Number	Monthly Amount (DA/Year)	Annual Amount (DA/Year)
	Internet subscription	1	2500	30000
	Electricity subscription	1	5000	60000
	Software License 1	1	2000	24000
	Software License 2	1	2000	24000
	Website Hosting	1	500	6000
	Cloud Computing Hosting	1	4000	48000
	Rental fees	1	45000	540000
	Total services	7	61000	732000
Total fixed charges (DA)				3972000

Table III.3. Fixed variables

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VI.2 Equipments

Equipment	Designation	unit value	Quantity	Total value DA
	imprement 3D	250000	1	250000
	Fair welding	10000	3	30000
	Pc	60000	3	180000
	wifi modem	6000	1	6000
	Total		8	466000
	Depreciationallowance 1 (over 5 years)			93200

Table III.4. Equipment

VI.3 Layout and installation

Layout and installation	Designation		Value (DA)
	Property		0
	Painter		15000
	Decoration		5000
	Various works		50000
	Installations	Electricity	0
		Water	0
		Telephone	0
		Others	0
	Total		120000
	Investment allocation (over 10 years)		12000

Table III.5. Layout and installation

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VI.4 Marketing

	Months												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
Monthly Budget (x1000 DA)	0	0	0	1	2	3	5	7	7	8	10	10	53

Table III.6. Monthly Budget

VI.5 Turnover

Goods/services			Months												Total
			1	2	3	4	5	6	7	8	9	10	11	12	
Product/service1	Units sold	S1	0	0	0	1	2	3	5	7	8	10	10	10	56
	Sellingprice(x1000 DA)	P1	0.000	0.000	0.000	200.000	200.000	200.000	200.000	200.000	200.000	200.000	200.000	200.000	///
	Turnover (x1000 DA)	T1	0.00	0.00	0.00	200.00	400.00	600.00	1000.00	1400.00	1600.00	2000.00	2000.00	2000.00	11200.00

Table III.7. Turnover

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VI.6 Results of the expected accounts

Charges(DA)	Sales(DA)	Profits (DA)
4054440	155247.14	2453159.96
Profit margin (%):21.90%		

Table III.8. Results of the expected accounts

VII. Experimental Prototype



Figure III.1. Prototype of smart irrigation

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VIII. Business Model Canvas

Conceived by:Belharizi Nesrine			Date :16/6/2024
Key partners	Key Activities	Customer Relations	Customers
- Equipment suppliers. -Agriculture Directorate - Distribution networks.	-Equipment purchase. -Doing tests. -Collect equipment and develop it with design. -Communicate with the Agricultural Marketing Directorate.	- Visiting farmers -Carrying out marketing in online sales sources (digital marketing) - Web advertising (targeted). - Conferences / exhibitions (platforms / seminars)	-Agriculture directorate -The farmer -Plants nursery
	Key Resources	Canals	
	-Sensors. - Electronic equipment. -3D printer machine. - Fair welding. - Service (market study, technical and financial study).	-Agricultural Directorate - Vehicles designated for delivery	
Cost Software development and maintenance cost, manufacturing costs of sensors and equipments costs related to training. Charges variables 82440.00 Charges fix 3972000 Profits 2453159.96		Income Sale of smart irrigation systems Maintenance and support contracts	

Table III.9.Business Model Canvas

Conclusions and Perspectives

The integration of IOT and AI technologies into irrigation systems presents a groundbreaking advancement in agricultural practices, significantly enhancing efficiency, reducing costs, and promoting sustainability. The low-cost smart farming solution leverages IOT devices for real-time data collection and AI algorithms for intelligent data analysis, enabling precise and timely irrigation. This approach ensures optimal water usage by adapting to real-time conditions such as soil moisture, weather patterns, and plant health. The synergy between IOT and AI facilitates automated, data-driven decision-making, leading to improved crop yields, resource conservation, and reduced labor costs. By making sophisticated irrigation technology accessible and affordable for a wide range of farmers, this solution supports sustainable agriculture, higher profitability, and better environmental stewardship. The project's success demonstrates the transformative potential of combining IoT and AI in modernizing agricultural practices and addressing global challenges related to water scarcity, food security, and climate change adaptation.

This platform will need more research that takes into consideration several perspectives:

1. To enhance the accuracy of the acquired data, we will increase the accuracy of low-cost sensors using autonomous and remotely managed techniques to improve the different calibration. As a consequence, our water–soil–plant–climate interaction models will prescribe more correct measures.

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