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IoT based Smart Irrigation System

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Abstract-A center pivot is a mechanized irrigation system type that irrigates crops in a circular pattern around a central pivot. Using Innovative IoT applications alongside center pivot irrigation systems allows for increasing agricultural labor automation, better water management, and cost rationalization and could aid farmers in making more informed decisions by giving accurate real-time data that is collected and analyzed for making better decisions in the future. Our system is making the irrigation process very easy since we are now in the age of the IoT systems and with our system, we can make the irrigation process depending on the parameters that we take and take a specific action that we can irrigate or not when we can start and end irrigation process and also the required amount of it.Our System presents another version of the irrigation process Technique and we are presenting it in our paper

Keywords- center-pivot, control system, monitoring, internet of things, single page application

I- Introduction

Population increase, limited resources, the influence of pandemics on the workforce, financial upheaval, and unpredictable weather conditions are putting unprecedented pressure on agricultural operations. As they attempt to feed the world, today's farmers must struggle with increased water shortages or floods, diminishing land availability, and shifting costs. Given the projected rapid growth of the world's population through 2050, farmers will need to boost food production by 70% to feed everyone [1]

Irrigation is the process of applying water to the soil, primarily to meet the water needs of growing plants. Water from rivers, reservoirs, lakes, or aquifers is pumped or flows by gravity through pipes, canals, ditches, or even natural streams. Applying water to fields enhances the magnitude, quality, and reliability of crop production. According to the Food and Agriculture Organization of the United Nations, irrigation contributes to about 40% of the world's food production on 20% of the world's crop production land. Various irrigation methods have been developed over time to meet the irrigation needs of certain crops in specific areas.

Nowadays, water has emerged as scarce in some areas. Who gets the water, and what will they pay for it? Irrigation and engineers might be in the middle of a number of these controversies. At a minimum, engineers will offer the information and strategies that policymakers will use to answer those questions. As such, engineers must have a familiarity with the cost of water and its distribution techniques. One critical idea that has emerged in latest years is the idea of virtual water. The cost of water depends on supply, demand, and the value of developing water assets.
The idea of virtual water assumes that if a country imports food, it's importing the amount of water required to develop that crop. As an example, if water for wheat requires 1,000 $m3/$ ton to produce, then importing a metric ton of wheat is the same as importing 1,000 $m2$ of water [2].

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Because of the increased demand for water resources, the price of water increases, and with it the value of effective water control. So, we should think about answers for the most optimal use of our water sources, and one of these solutions is the center pivot irrigation device. And with our system, we can save Water and Money, which there will be no waste of water and it will irrigate exactly the amount of water that is needed.
Also, it helps us to get ready for the world's water future One-third of the U.S. now pays more for water than electricity. Water rates are continuing to rise, and water is generally a top operation cost. The cost of water is rising faster than all other utility costs. Those rates will continue to rise to pay for infrastructure improvements.

Also, in (December 2019) Another paper is published in the International Journal of Innovative Science and Research Technology This paper discusses an automated watering and irrigation system which can supply water to the crops when needed as well as adjust the amount of water supplied depending on the soil moisture content. The sensors sense moisture content by sending an electrical current through the soil and measuring the output resistance they also used an ESP (8266) the data from the sensor is sent to the Arduino which is connected to the Wi-Fi Module (ESP-8266) which sends data to the (Thing Speak) server. [4]

Also, the paper talked about monitoring the soil parameters using soil moisture like moisture sensors then analyzing these data and taking required irrigation actions using Node MCU (ESP8266) to communicate with the motor and pump as well as opening the valve of solenoid valves. [5]

This paper is presenting several previous versions of the automated and smart irrigation system, and our system scope is to make the whole system become automated since it presents how we can make irrigation depending on the parameters that we give to the main controller to start the irrigation process.

II- IOT applications for center pivot system

IoT applications use a variety of sensors to collect data in real-time. Farmers and agronomists use linked sensors to examine soil conditions and track crop health. As time goes sensor technology advances and Farmers will have more options to apply sensor technology to their circumstances thanks to low-power, miniaturized technologies with the power of 5G [6].
Crop health must be maintained 24 hours a day, seven days a week to ensure farm productivity. With creative solutions that lead to comprehensive, actionable, and data-driven insights, agriculture IoT developers can assist farmers in monitoring and maximizing output.

A. Remote Sensing

Remote monitoring capability is provided to save money by reducing water resources and labor while staying informed of conditions wherever, anytime, and across the farm using remote sensing technologies and connected devices. Sensors produce real-time data that may be evaluated to assess current processes and make modifications for improved efficiency and effectiveness. With confidence, respond to inter- and intra-field variability, control irrigation, and keep an eye on crops.

B. Precision Farming

Real-time data collection, comprehensive analytics, and linked sensors can help you fine-tune your response to crop variations. IoT agriculture solutions help farmers understand the operations of their business better.

C. Smart Irrigation

Water waste can be reduced, crops can be kept healthy, and yields may be increased by using networked, sensor-based water monitoring and management. Farmers may use sensor data and analysis to regulate irrigation in a way that meets demand while also conserving natural resources. Over time, sustainable methods boost revenue while conserving water.

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III- SYSTEM DESCRIPTION

A standard center pivot system consists of a pipe structure supported by towers that pivot around a center point. Along the pipe, nozzles are equally spaced and controlled by a control panel placed in the field. As it rotates, water is released from the nozzles and irrigates crops. We endeavored to incorporate the smartness aspect to the system by making the system always in contact with the user by sending those data about the conditions of the field and giving the user the ability to remotely control the system. The interaction between the user and the system is done by a mobile application and a web application with an easy-to-use interface. In the following, there's a block diagram that identifies the whole system for us in a simple way which is as follows.

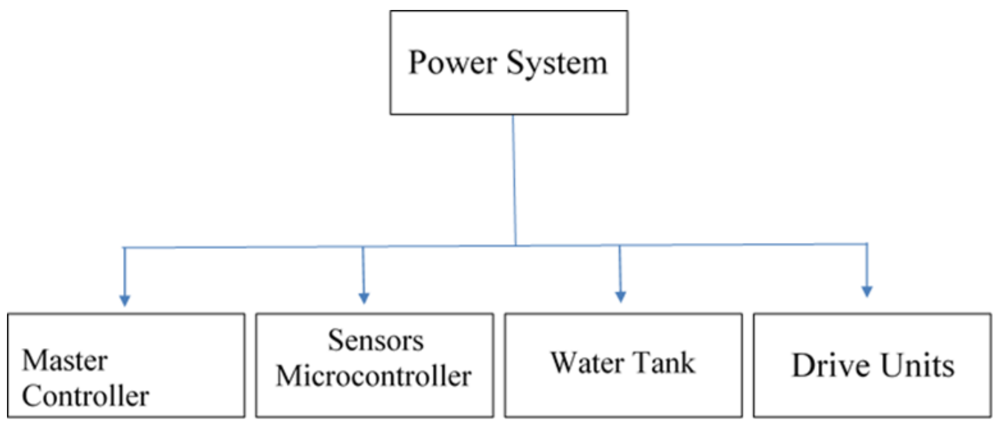

Figure 1: System Description

The smart irrigation system that we designed has several tasks to do first, it starts with measuring the soil parameters and air temperature using soil and temperature sensors and then sending these data wirelessly using a WIFI module to the main microcontroller to analyze these data. The main microcontroller part receives sensor data and takes decisions based on this data, the data from the database, and the day of irrigation it starts the irrigation order with details and sends these orders to a water tank and drives units wirelessly. And for power efficiency, we used solar power for our system. So generally, we can summarize the system in these main points:

1) Master controller
2) Sensor's microcontroller
3) power system
4) Water tank
5) The cars (drive units)

A. Sensors' control system

The sensors' microcontroller system is a system that consists of a microcontroller that acts as a "slave controller" and is used to receive the sensors' data from the sensors used in the system and send it back to the main microcontroller which acts as a "master controller". The microcontroller used is ESP32 for each slave and master microcontroller. And consists of sensors connected to the sensors' microcontroller which are: the soil moisture sensor, DHT22 sensor, and rain sensor. Each of these sensors has a specific task to do, which will be explained. The figure below (fig.2) shows the Block Diagram for the Sensors System to explain how to use the Sensors system as follows: -

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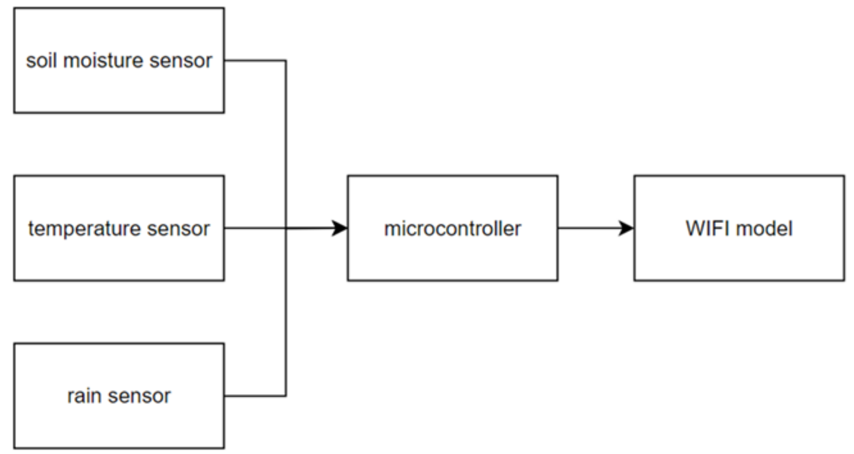

Figure 2 Sensors' Control System

1. *Soil* Moisture Sensor

The soil sensor is used to measure or estimate the amount of water in the soil. After estimating the amount of water in the soil, we can determine if the soil needs water or not. Then we measure the amount.

2. DHT22 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.

3. Rain Sensor

The rain sensor is used for detecting if there's rain or not, which's a crucial thing for the system work upon. Knowing that there's rain determines the whole process, that's why it's the first step in our design to check if there's rain or not. If rain exists, the system stops irrigation till the rain is done. So, I the previous points you now get that how the sensors system is operating and in the next figure you can find out our hardware circuit for the sensor's system

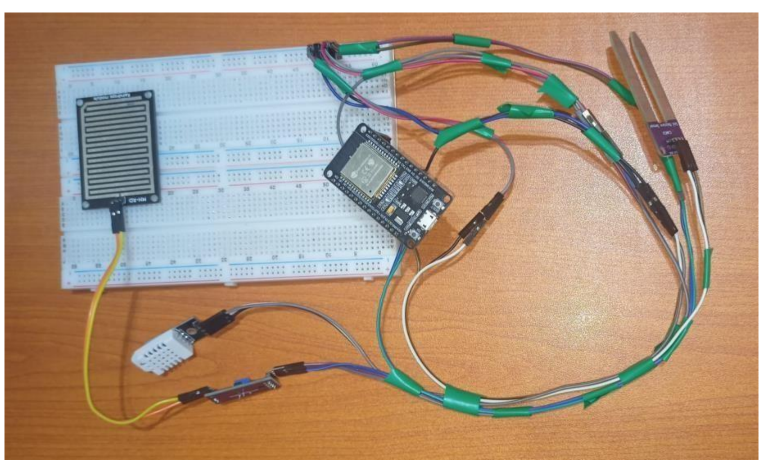

Figure 3: Sensor's Design

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B. Master Control system

The master control system is the main system that connects and controls the whole system. The master microcontroller is connected to the drive unit microcontroller and the microcontroller of the sensor The master controller has the scheduling database of irrigation and fertilization of each crop which accordingly the system takes action. By having each crop's irrigation and fertilization schedule and sensors' data, the system becomes more accurate and efficient. The schedule and conditions that we are using are from the Ministry of Agriculture. The master and slave microcontrollers were programmed using Arduino C. There are two processes that occur in the master microcontroller

1) **Plant Selection Process:** It's the process of selecting the crop the user wants to irrigate, and accordingly the master microcontroller determines which schedule it'll use for that specific crop. And the corps that we used to irrigate with isthe Wheat Corp which has as significant important for Egypt now days

2) **Irrigation and Fertilization Process:** After selecting the schedule for that specific crop, it starts the irrigation and fertilization process according to the schedule and the sensors' data which the main microcontroller (master) receives from the sensors' microcontroller (slave).

IV. SOFTWARE DESIGN

The aspect of smartness in our system is the most important thing in the project, without it will be just a regular irrigation system. It opens to numerous perks such as giving the opportunity to remotely monitor the irrigation field and remotely control the irrigation operations with a web application and a mobile application which yields cost and energy savings.
The following Block Diagram is presenting the whole software Design which we can define the process of the system as follow:

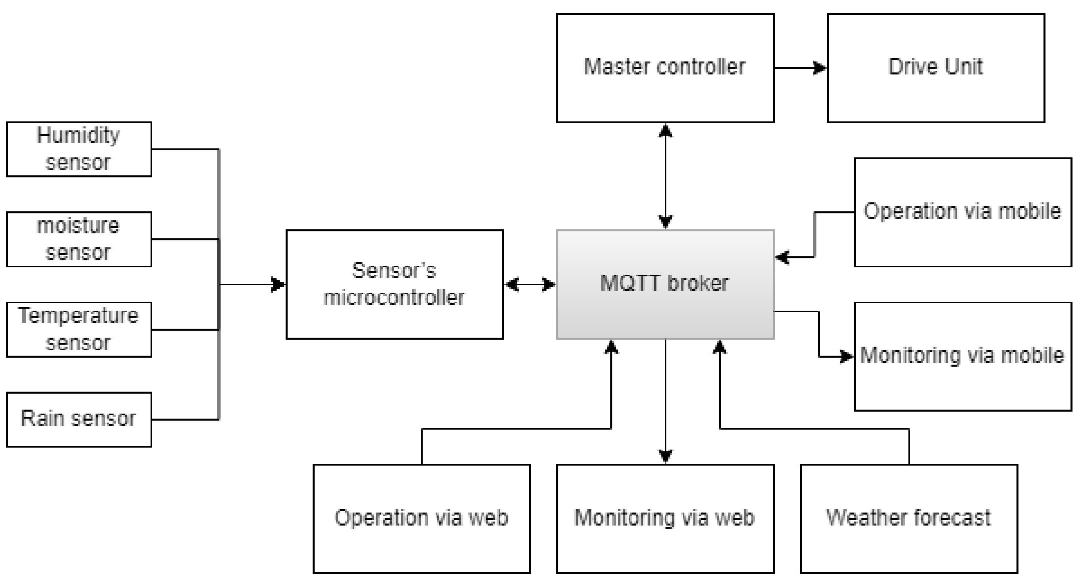

Figure 4: Software Design

Form figure 4 it is illustrated that the sensor on the field sends the data by messaging protocol called MQTT to intermediary entity called MQTT broker, then the sensor 's data is sent to the mobile application and the web application to be displayed to the user in real time. The system operates in both ways, it means that the web application and the mobile application can send data/commands to the master controlled to start the irrigation process. The system is smart and can make decision on its own by deciding to stop irrigation if there israin on the field and determining autonomously the amount of water based on the crops need for water and amount of fertilizers that is needed for the Crop. We can also use the system in manual mode.

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A. MQTT

To connect the control system with the cloud and be able to monitor and operate the system remotely we used the MQTT protocol.

MQTT is a simple messaging protocol created for low bandwidth. It is a simple publish/subscribe protocol that allows clients to both publish and subscribe to messages. All messages must be received by the MQTT broker, the broker filters them, and then determines which clients are interested in the message, and broadcast it to all clients who have subscribed. The data that is sent through MQTT is called Application messages [7].

An MQTT client is any software or hardware that may exchange application messages over a network using MQTT. Both publishers and subscribers are possible for MQTT clients. Application messages are published by a publisher after being requested by subscribers [8]. In our case, the MQTT clients are the microcontroller in the field, the mobile application, and the web application.

B. Mobile Application

To develop an application, first we need to write down our thought process about it and then draw it logically as in the flowchart below, so that the implementation and development process would be easier and clearer. Our mobile application will have two pages, one for monitoring the sensors. The application would receive data from sensors via MQTT protocol. The other page is for operation; where we can automate the system and also stop the automation. In some cases, we would need to stop the automation process if some erroroccurred in the system or maybe if the farmers need to interfere with the irrigation process for various reasons. So, we'll need to develop some reliable way for them to be able to stop the process anytime they need to.

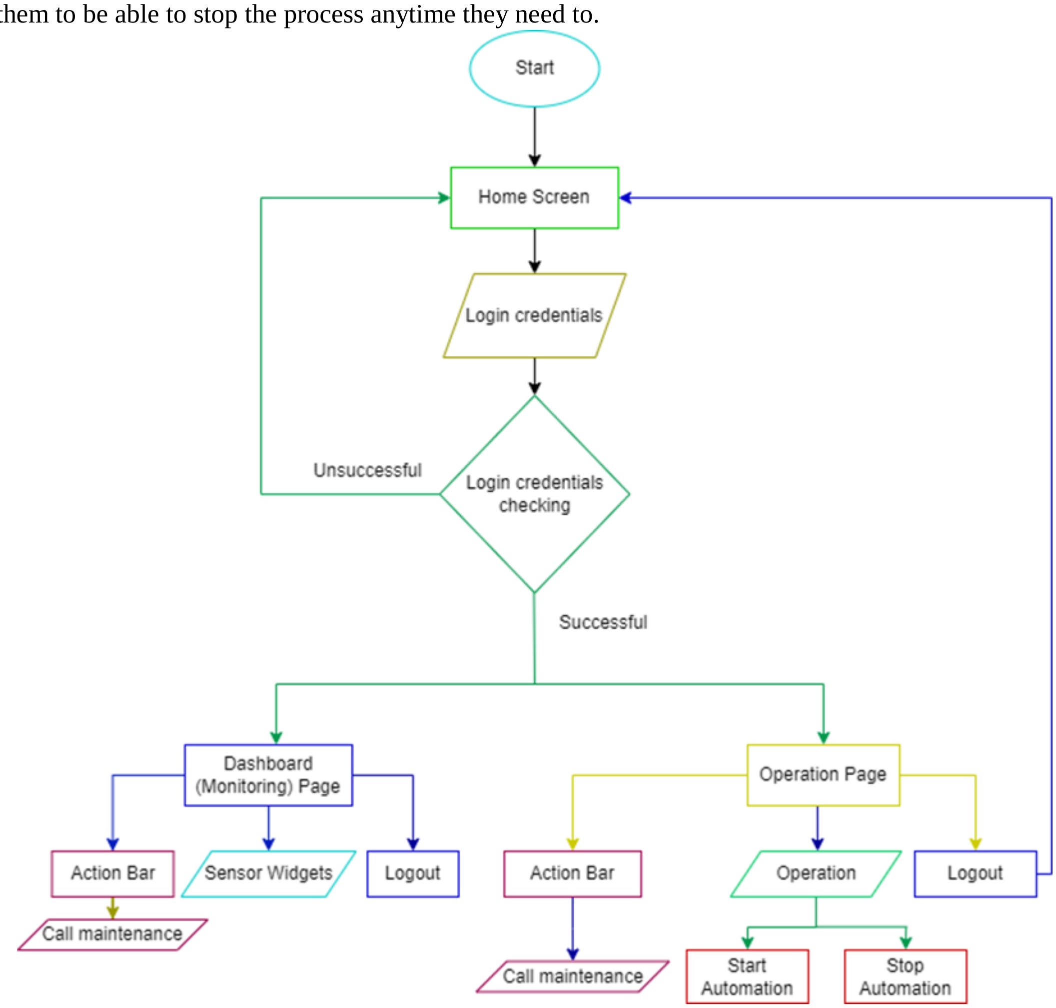

Figure 5: Mobile Application's Design Flowchart

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The mobile application was developed using Flutter. Below, we'll showcase some screenshots of the UX design of the mobile application, which consists of 3 pages: login page, monitoring (dashboard) page and operation page. The login page requires the user authentication to ensure that a valid user is using it, while the dashboard page is used for monitoring the sensors measurements remotely. The operation page is used to either start automation or stop it by the ON/OFF button.

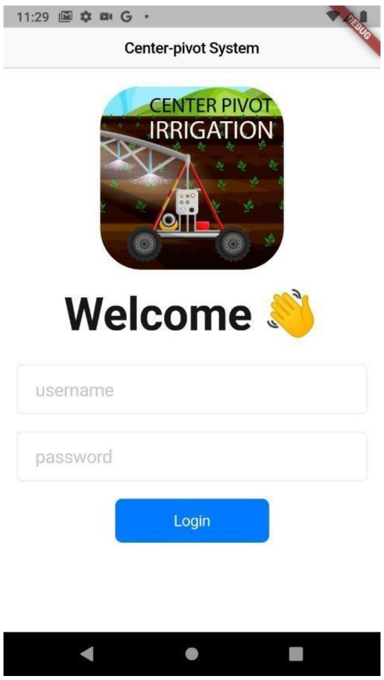

Figure 6: Login Page

Figure 7: Dashboard Page

Figure 8: Operation Page OFF

Figure 9: Operation Page ON

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C. Web Application

A web application could be used on a laptop, pc, or mobile phone. It allows the user to monitor the irrigation field and control the irrigation operations and also know the weather of the current day and two days after, giving the user time to prepare for unfortunate weather. Building the web application entails learning some web development languages and frameworks, each language has its purpose and is essential for a certain aspect of the web application.

HTML: Hypertext Markup Language is used to create web pages' front ends using a markup language. It serves as a website's skeleton [9].

CSS: Cascading Style Sheets specify how the content of HTML should appear. Its main concern is presentation; the presentation of a page refers to how it appears. Fonts, colours, background pictures, line spacing, and page layout [9].

JavaScript: JavaScript is a coding language that makes it possible to create interactivity and behaviours to web pages and alter web page’s components [10].

Angular framework: Angular is a JavaScript framework that is open-source and developed in Typescript. Its main objective is the creation of single-page apps. Thanks to the modular environment that angular has we can build the web application in a manageable way [11].

i. Single-page application concept

A single-page application is a type of web application where most of the data remains the same and just a tiny portion is changed or updated at once. Choosing a single-page application over a Multi-Page-Application was an obvious choice since a Single-page application uses less Bandwidth because a single-page application loads web pages once, it needs less bandwidth. so, it will do well in areas with a very slow internet speed

ii. Web application pages

Our web application contains numerous pages, each one is built to fulfil a certain objective and offers an imperative application to the user, it is connected to the system on the field constantly, as long as the system is on the user can monitor the field by the sensors and execute irrigation operations. Not only the web app is made for the system owner but also it contains an overview page that is available publicly to those who might be interested in buying the system as a product

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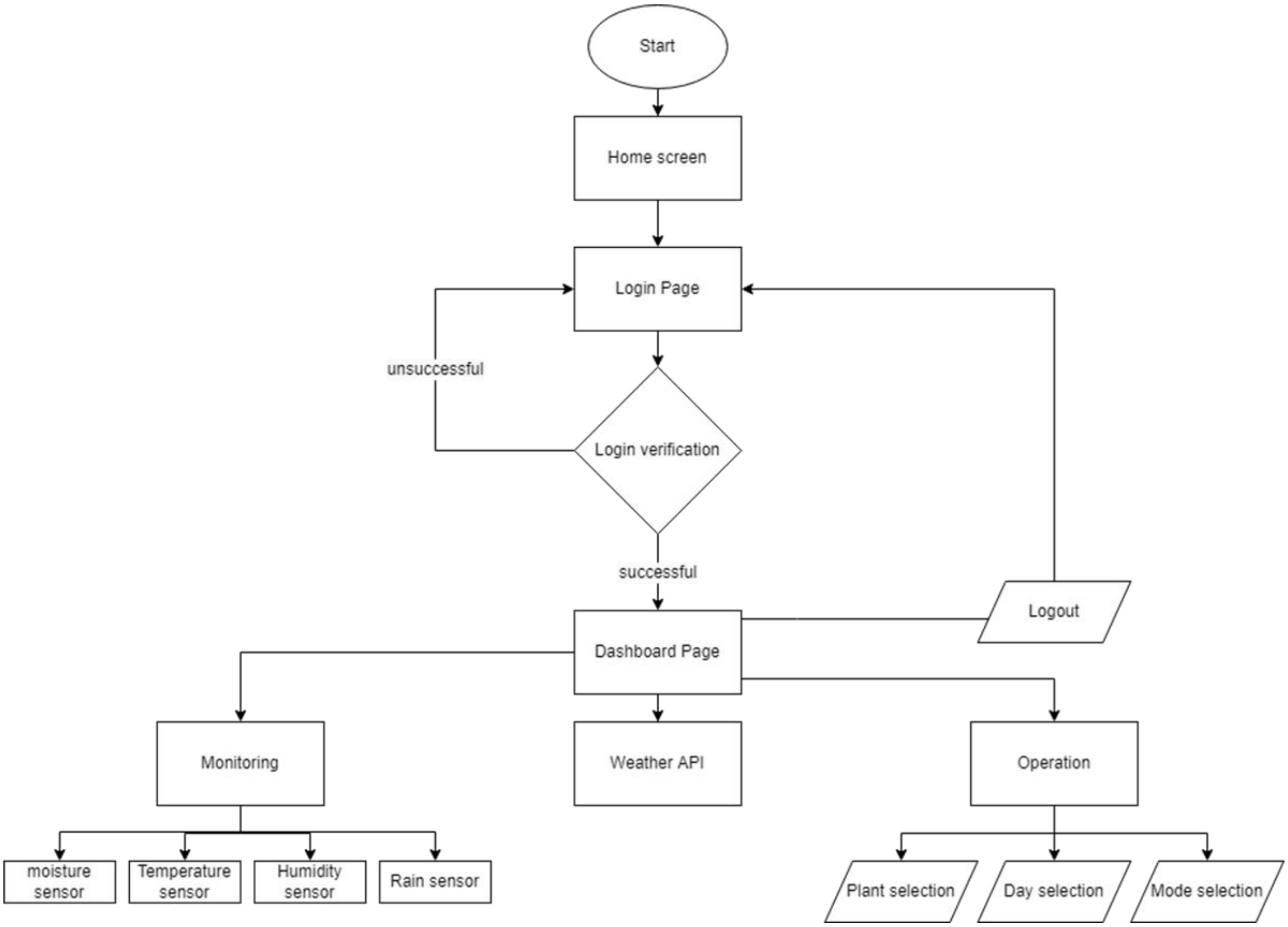

Figure 10: web application architecture

1. Login Page

The web application requires a user authentication by entering a certain username and password in the login page before accessing themonitoring and operation page.

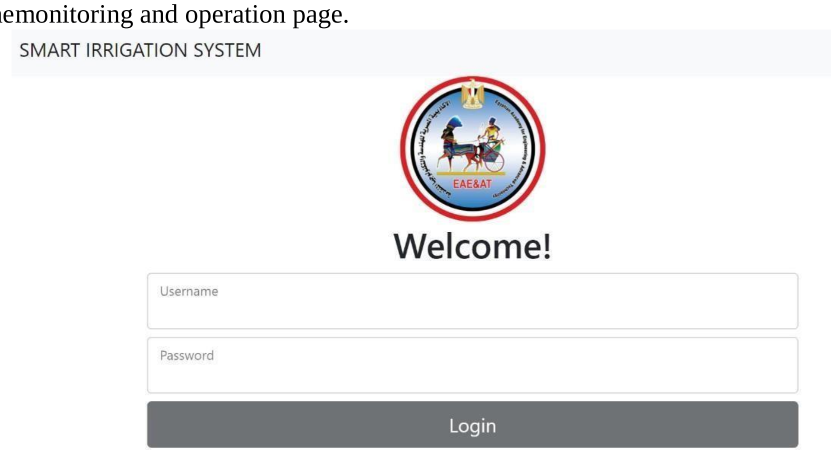

Figure 11: Web Application's Login Page

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2. Monitoring Page

The system is publishing moisture, humidity, rain and temperature readings on topics on the MQTT broker then the web application receives these sensors data by subscribing to the same topics then displays the data; allowing a simple user to read these values in an easy fashion.

Figure 12: Web Application’s Monitoring Page

3. Operation Control

In this case the web app is the one that publishes data to the topics and the system’s microcontroller is the one that subscribes to the topics, taking these data as certain commands for operations. The user has the option to choose between different crops, and whether to start the irrigation process now and begin an irrigation time interval from the start or give the system a certain day to start from or leave the system at standby mode waiting for further instructions. The user has also the option of inserting the crop’s current state of the amountof acid and potassium and urea or just makes the irrigation at auto mode which starts irrigation with the values of the standard state of values of the crop.

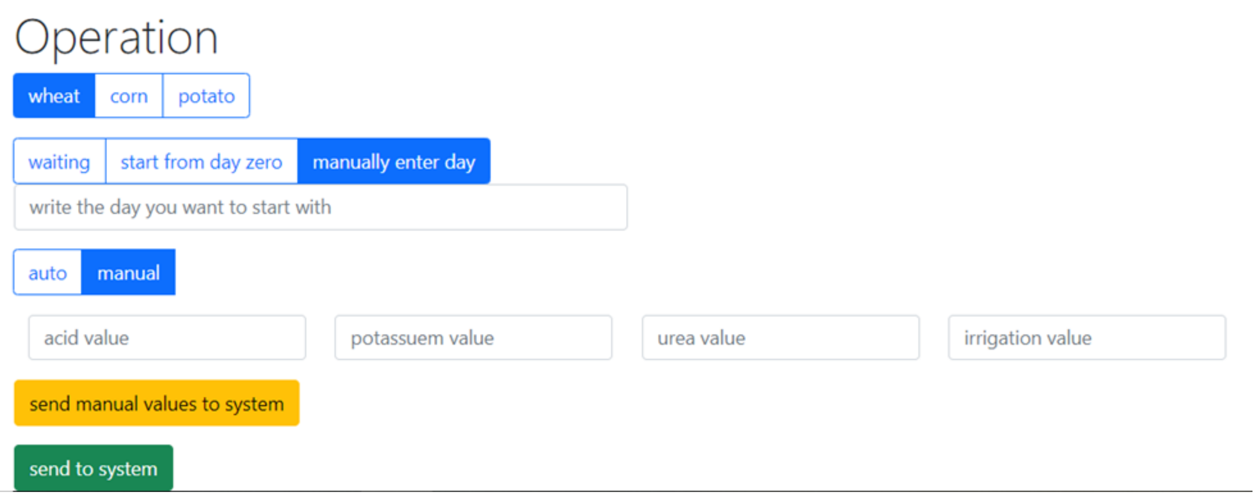

Figure 13: Web Application's Operation Page

4. Weather forecasting

Weather forecasting on the web application is done using weather API. A Weather API is an Application Programming Interfaces that give you global access to current and historical weather data[9], it gives prediction that is accurate and in real time. The current and forecast weather conditions and the weather predictions for 2 days later in figure 14.

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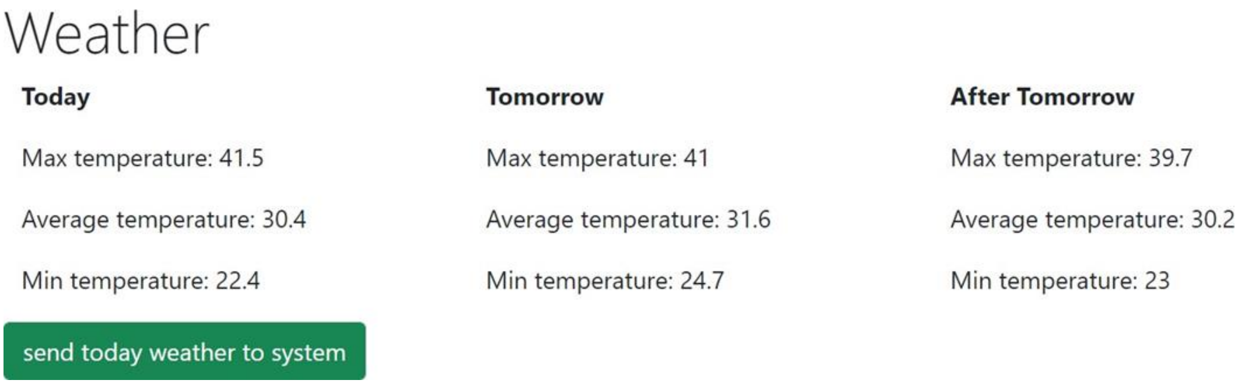

Figure 14: Weather forecasting in web application

V- CONCLUSION

In this research, a smart center-pivot irrigation and fertilization system was designed and implemented. The control system and subsystems were designed and explained. ESP32 was used as a microcontroller, and it was programmed using Arduino C. Internet of Things (IoT) and cloud server technologies were used to make the operation of this system smarter and more reliable. MQTT protocol was used to send and receive data from sensors to the web or mobile applications and vice versa. The data is monitored through mobile and web applications in real-time.in our proposed system we fixed several problems like the waste of water and the huge amount of wasted water so, we can know that our system's smartness comes from that it can decide whether it can start the irrigation process or not and also the needed amount of water depending on the needs of the Corp for water and also committing to the needs and the schedule for irrigating the plant itself and the number of fertilizers that are needed for the Corp itself and important thing that the system irrigation process can be blocked if like if there was raining it won't rain and the connectivity is very high and also we can use the system in manual mode and I hope this paper will help you and guide you for more progress in irrigation systems.

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