IoT Smart Irrigation System for Precision Agriculture

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Abstract. Agriculture is one of the main sources of income in the economy. One of the key components in an agriculture system is its irrigation system. The efficiency and practicality of the irrigation system will have a direct impact on crops yield. One of the main challenges for an irrigation system is water scarcity. Another challenge is time, based on the used irrigation system the task of watering the field could be labor-intensive and time-consuming. To maximize crop yield, farmers must practice precision agriculture, and that is another challenge. A smart irrigation system is part of the solution to practice precision agriculture and thereby getting the most from what resources are available.

This paper presents a smart irrigation system that addresses the three mentioned challenges to pave the way for a solution to precision agriculture. The system will measure the water tank levels, soil moisture, humidity, temperature, rain levels and will fetch the weather forecast for temperature and rain levels and using its algorithm it will decide when to start the irrigation process and for how long. The system will provide the farmers with a web portal that contains the system status that's includes water tank level, water pump status, weather forecast, sensors measurements.

Keywords: Precision Agriculture, Water Scarcity, Smart Irrigation, Internet of Things (IoT), Arduino, Raspberry Pi.

1 Introduction

Agriculture is one of the most important pillars of the economy and the stability of society depends on the stability of the availability of food commodities. All societies aspire to obtain this stability by producing what the society needs of food commodities locally, to do so societies seek to reclaim land, provide water sources, invest in the agricultural sector and work on developing it to reach the best yield from the available sources of land, water, and labor.

One of the ways to develop the agricultural sector is to work on improving the used irrigation systems. In traditional irrigation systems, the farmer manually and periodically starts the irrigation process. The worker determines the time intervals for the irrigation process and between them by visual observation, which may not be accurate due to the different levels of saturation between the surface of the soil from within, and this may lead to ineffective irrigation of crops and waste of limited water sources.

Or the opposite may happen, an insufficient and irregular irrigation will have a negative impact on crops health and yield.

The Internet of Things (IoT) movement plays a major role in the development of various fields, and it does so by providing smart and easy-to-contain solutions to traditional and emerging problems.

IoT plays an important role in many areas, one of that is agricultural sector by which in future it will aliment millions of individuals on the earth.

Precision agriculture relies heavily on the technological solutions that IoT provides, adopting at a wild scale for precision agriculture by the help of IoT will help to provide aliment to all societies in the future.

This paper presents a smart irrigation system that deals with water scarcity and adapt the irrigation process based on the availability of water in the main tank and weather conditions while keeping the soil moister level within a certain range that is best for the farmed crops.

The system will consist of a main station that runs on a raspberry-pi as its core computing station, a multiple side stations as sensory stations based on the farm size and crops variation that run on Arduino UNO and multiple water pump stations that receive control signals from the main station based on how farm irrigation system divided and what type of crops in each field.

2 Literature Survey

This field of study is well saturated with experiments on this subject. The researcher's focus is on the soil moisture levels as it's a key indicator for the irrigation process. The system design varies from research to another some of the researcher's focus was on the communication part of the system, other on the energy source for remote stations. The proposed system design will address varies fields of a smart irrigation system.

In [1], the researchers automate the irrigation process for a traditional irrigation system using the measurements from a temperature and soil moister sensors to a PIC16f877A micro controller that controls a water pump. The system uses a feedback mechanism to the user in the form of a GSM messages and messages on small LCD screen that displays the system status.

In [2], the researchers use the soil moisture measurements as input to an Arduino UNO board that controls a water pump through a relay, and they provide the farm status to the user through an Android application. And their goal is to maximize crops yield and reduce water and electricity usage.

In [3], the researchers proposed a system that focuses on water recycling and maintaining water pump health and they used the water level as factor in the irrigation process. The system uses an Arduino UNO board with a combination of sensors and multiple water pumps. User interaction with the system is limited with a small LCD screen that's loops system information and status.

In [4], the researchers use K-NN machine learning algorithm with inputs as the soil moisture level and the temperature then predict the soil moisture level and use the result to control a water pump. The researchers didn't clarify how they option or build the dataset and other system details like the frequently of measurement is not clarify. In this paper, the research didn't experiment on how the system decision based on prediction is besting the traditional decision based on real sensory data.

In [5], the researchers automate the irrigation process for a greenhouse irrigation system using the measurements from a temperature, humidity, and soil moisture sensors to a ESP8266 microcontroller that controls a water pump and a fan by two relays. By doing so, the system keeps the greenhouse soil temperature and moisture levels at the optimal levels. The system uses a feedback mechanism to the user in the form of a mobile application connected to a cloud that display the system status.

In [6], the researchers create a Wireless Sensor Network (WSN) that connects to a main station using XBee ZigBee modules. The main station controls the connected solenoid water electrical valve to automate the irrigation process based on the measurements from soil moisture. By doing so, the system keeps the moisture levels at the optimal levels. The system utilizes a cloud portal to present the field status to the farmers. The researchers focused on system physical and software security by using cameras surveillance system and encryption.

3 Objective

Precision agriculture is the future. One of the main goals of precision agriculture is to utilize the available resources to it max with minimal resources wastage. The main objectives for this system:

- Using IoT technologies to automate the irrigation process and save farmers time and money spent on this process.
- Cut the farmers spending on water and electricity by managing the available resources with maximum efficiency.
- Managing the water resource by addressing water scarcity without impacting the crops health.
- Maintain the farmers up to date with fields and crops real time status.

4 System Design

4.1 System Architecture

An overview of the general system architecture is shown in Figure 1.

In the proposed system, there are one main station and multiple control and sensory stations based of the farm fields and crops. The main station consists of a main controller (Raspberry Pi board) and a power supply to power the board. The main station receives data input from the sensory stations, the weather forecast API (open weather API) and users' direct control from the user portal. The data from the sensory station represent the sensors measurements and the data from the weather forecast API represent the forecasted temperature and rain chance and users input data is a control command to the main controller. The main board outputs control signals to the control statins and field status to the user portal. The control signals the control stations used to control the water pump status and the output to the user's portal is a representation of the reading from the sensory stations and the weather forecast API. As for the used connection to the main board the AC power supply is directly connected to the board, the system utilizes a wireless connection using ZigBee to the sensory stations and the control stations and the main board is connected to the network using Wi-Fi to provide the user portal server and connect to the weather forecast API.

The system utilizes an Arduino UNO micro controller as the board for the sensory stations that receive measurement's reading from the sensors (moisture, rain, humidity, temperature) as data input and output those measurements to the main board. It receives power from the solar panel kit that is directly connect to the board. The solar panel kit consists of the solar charger shield those interfaces with the Arduino board to regulate the current and voltage, a battery to store electrical energy, and a solar panel to charge the battery. The sensory station connects to the main station using ZigBee wireless protocol and the sensors are directly connected to Arduino board.

The control station consists of a microcontroller (Arduino UNO) and a relay. The relay is directly connected to the Arduino board and to the water pump. The Arduino board connects to the main station using ZigBee wireless protocol and receives inputs from the main station as command signals to control the relay that control the water pump.

The water tank station consists of a microcontroller (Arduino UNO) and an ultrasonic sensor. The Arduino board connects to the main station using ZigBee wireless protocol and sends the tank's water level as inputs to the main station.

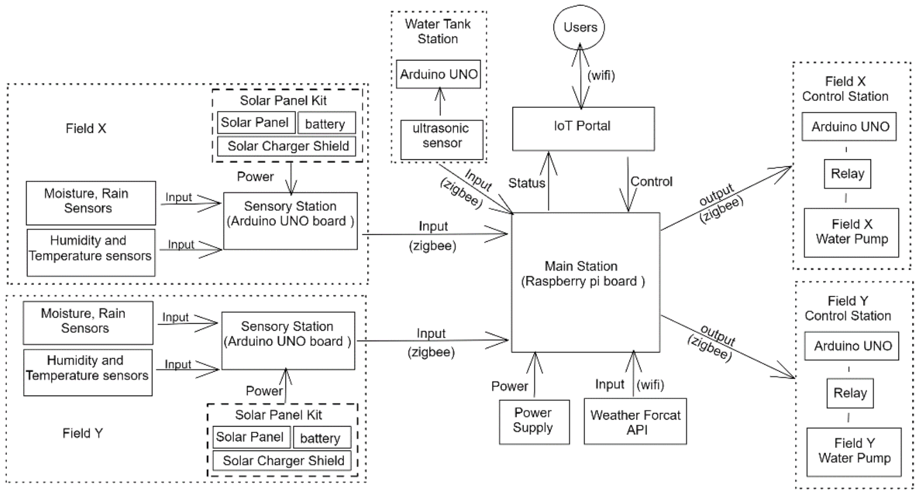

Fig. 1. Block diagram of Smart Irrigation System.

4.2 Proposed Methodology

The proposed methodology will be presented as two stages. The first stage when the system starts, it presented in Figure 2. In the system initiation stage the system will load the crops and filed reference metrics that will be used in the decision-making process, then the system will check for user update on those metrics, the user will be able to change the fields layout and crops type and their reference values, if there is no update to the reference metrics values the system will proceeds with irrigation process.

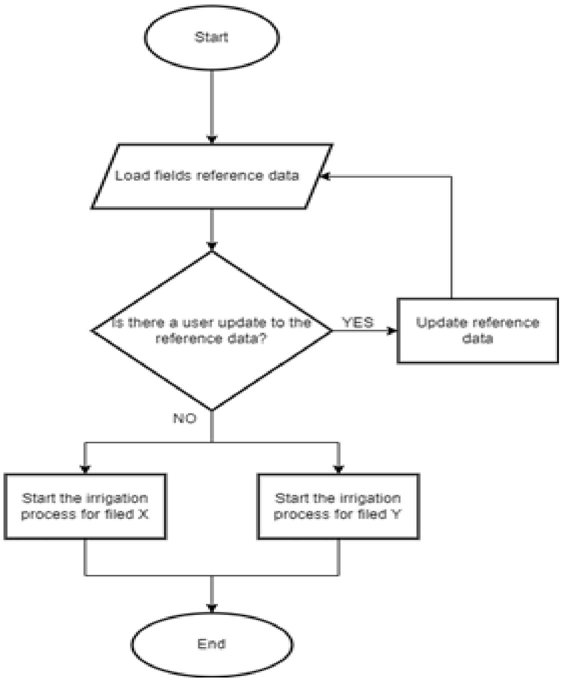

Fig. 2. System Initiation Process.

In the next stage, the system will start the irrigation process as presented in Figure 3. The process starts with the water pump status is off and if it's a startup process the system will proceed to the next stage without entering the sleep status, else if it's a user direct control to turn off the water pump the system will adjust the sleep timer based on user configuration, else if it's a system control to turn the water pump off it will proceeds to the next stage without updating the sleep timer. In the next stage, the system will acquire the sensory data from the fields sensory stations and the water tank station.

First the system will check the rain sensor and based on its reading, it will decide whether to restart the process or to proceed to the next step. In the next step, the system will fetch the weather forecast by contacting weather forecast service API and it will use the element of the rain chance and compare it to the threshold value and decides whether to continue the process or restart it. In the next step, the system will compare the reading from the moisture sensors and compare them to the threshold value and decide to proceed to the next step or to restart the process. Next, the system does the same for the temperature and humidity sensors reading and if it passes all these steps, the system will turn the water pump on for a certain amount of time that depends mainly on the water level in the tank and the sensory data form the sensory station. If the system receives a direct control to turn the water pump on, it will do so for a specific time set by the user. After a change in the system status, the user portal gets updated with the new values.

4.3 Implementation

The proposed smart irrigation system is designed to keep the crops in an optimal condition with minimal water wastage and human interactions. The design implements IoT mechanism using raspberry pi as the main station that host the user portal and connected to a weather forecasting API. Arduino UNO Boards as sensory and control stations. A solar kit to power the sensory stations. The system utilizes variety of sensors to sense soil moisture at deferent levels, rain, temperature, and humidity levels, ultra-sonic sensors to detect water levels in the tanks. And relays to control the water pumps.

The main station fulfills six unique cases that may emerge during the irrigation process. They are as follows:

- Case1: The system receives a direct user control to turn the water pump on or off for a specific field, that will cue the system to overwrite the automatic process for a period specified in the system configuration.
- Case2: This case is significant for water preservation. The system reads water level in the tank from the water tank station, and if the level is less than the configured value, it will adjust the water pump on/off time for that level until the level exceeds the configured threshold.
- Case3: If the system received a rain chance with a certain level from the weather API or the system sense rain falling, it will turn the water pump off until those status changes.
- Case4: If the system detects a low overall level of moisture from the moisture sensors in a specific field, it will turn the water pump on for that field until their reading changes or get overwrite from other sensory data or direct user control.
- Case5: It’s the same as case 4 but regarding temperature and humidity reading.
- Case6: Finally, in case of power breakdown all water pumps will stop, But, when power supply will be available, user has not required to start out the process manually, due to program composed into the main station and the microcontroller stations it will automatically get started with less or no user interference.

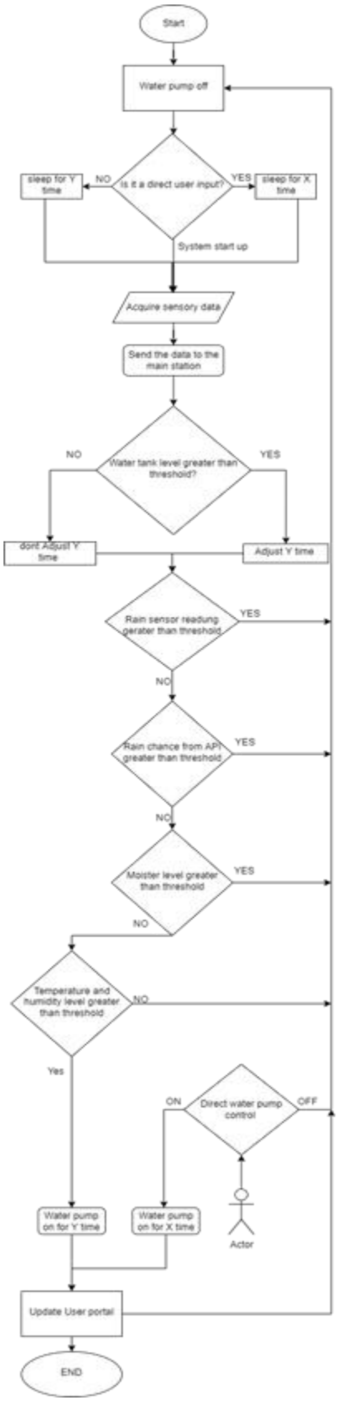

Fig. 3. System irrigation process.

4.4 Proposed System Components

The system components are categorized into two types, hardware and software components and they are explained as follows:

- **Hardware Used.** The followings are the hardware components used to implement his system:
  - *Raspberry pi 3 b Board (Main Station)*. The Raspberry pi acts as the brain of the system that host the algorithms to control other station, the user portal for user interface and interactions, API communications and main station to other stations communications. It was chosen to act as the main station due to it computational power and its ability to run different software products.
  - *Arduino UNO Board (Microcontroller Board)*. It acts as sensory stations, water tank station and control stations. It's responsible for sensory reading and communication with the main station and receiving controls to issue to the water pumps. We use the Arduino UNO or a similar microcontroller because of its low power consumption, support of analog or digital inputs, and the wide availability of a variety of kits.
  - *Sensors.* The system utilize a variety of sensors. Moisture, rain, temperature, humidity, and ultrasonic sensors. Their reading is used as input to control the system states.
  - *Solar Panel Kit.* This kit consists of a solar panel, battery, and a solar charger shield. And its function as a power supply for the sensory stations.
  - *Water Pump.* A pump that used to take water from the tank to the field's water pipes.
  - *Relay.* In this system we are using Relays for controlling the status of the water pumps. A relay is nothing but a switch that electronically opens or closes circuit.
  - *Pipes.* used as a water channel for the flow of water for fields.
- **Software used.** The software used in this system are as follows:
  - *Raspbian OS.* Used to run the Raspberry pi 3 b (main station).
  - *Python 2.7.* Used as a scripting language to program the algorithms.
  - *Flask framework.* Used to create the user portal, utilizing HTTPS protocol with authentication and authorization. The portal present system status and provide control mechanism to control the system
  - *Arduino ide.* Used to write the programming code and then transfer it into Arduino board stations.

4.5 Electric Circuit Diagram

To implement the system model in a laboratory, a circuit and schematic diagrams were created. The main station is not included in the diagrams, because the only physical connection to the board is the AC power.

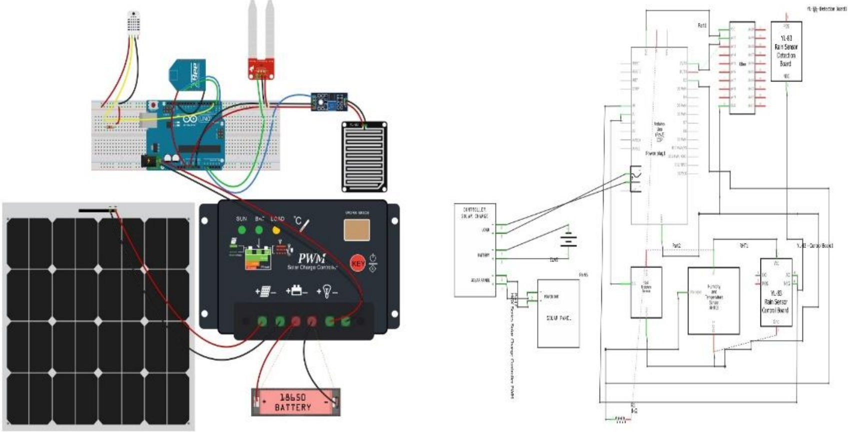

Fig. 4. Circuit and Schematic diagrams of a sensory station.

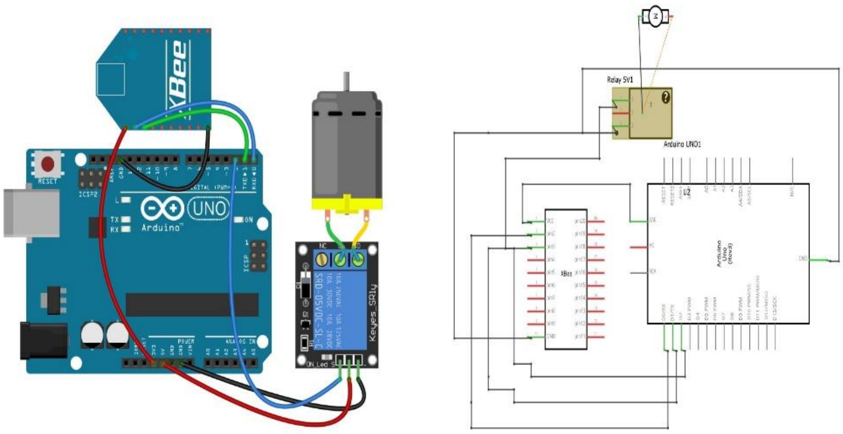

Fig. 5. Circuit and Schematic diagrams of a pump station.

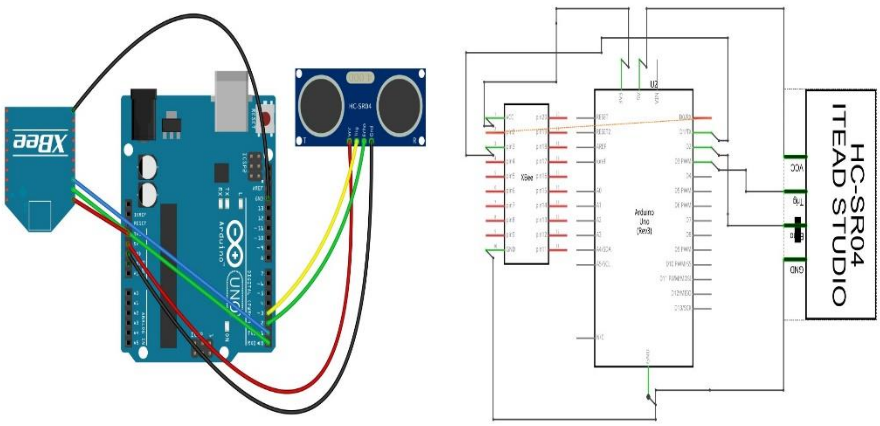

Fig. 6. Circuit and Schematic diagrams of a water tank station.

5 Discussion and future work

In future improvement of the proposed model, we can address system software and hardware security in more details. In this paper we address some software security aspects, such as using ZigBee for wireless communications and its supports for encryption, using HTTPS, and supporting authentication and authorization for user portal access, and the use of updatable software packages. Integrating smart fertilization along with smart irrigation by sensing the chemicals in the soil. And generating and using a plant's database that includes crops water and fertilization needs at different stages of the plant's life cycle.

6 Conclusion

The quality and efficiency of the irrigation system in agriculture is a key factor to the success of crops. Water scarcity, desertification, and food shortage in many areas in the world has mad precision agriculture a necessity. From that, the idea of a smart irrigation system developed by utilizing new technologies in the field of IoT and new technologies in the field of agriculture to reach the goal of precision agriculture. This paper presents a model of a smart irrigation system that supports different fields and different crops. The proposed system utilizes sensory stations in each field that measures the soil moisture levels along with air temperature, humidity, and rain intensity and communicate that information to the main station wirelessly through ZigBee, in the main station it uses that information along with weather forecast to control the irrigation process, with an option of manual overwrites by the user. The system beneficial in reducing water wastage, keeping the crops in optimal conditions, reducing the need for manpower, save time and always keeps the farmer aware of the farm conditions. There are some limitations to the system, that’s include physical security of the sensory stations, the distance between the sensory station and the main station.

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