Internet Of Things: Smart Irrigation System

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Abstract.

To sustain the rising demand for water for agriculture, this research paper presents a smart irrigation system with the use of the Internet of Things (IoT) which can help to minimize manual labor and water wastage. This paper consists of numerous literature reviews where different sensors and components used in current irrigation systems were investigated and the use of IoT technology in irrigation systems, as well as the obstacles to be faced, was explored. This paper aims to develop an IoT-based smart irrigation system using a microcontroller and various sensors to improve existing systems for the comfort and convenience of users not only by monitoring moisture and weather data but also by monitoring any intrusions, water in a storage tank, and also faulty parts in the system through the use of a user-friendly mobile application. The results and limitations of our proposed system will be discussed and suggestions to improve our system further will be given.

1. INTRODUCTION

Irrigation in farming has existed since ancient days and it remains to be the largest consumer of water, which necessitates the regulation of water supply for irrigation activities. Modern-day agriculture businesses have leveraged on Internet of Things to reduce manual labor, water wastage, and consumption, as well as to improve the yield of their crops. A smart irrigation system works by integrating a network of sensors with the irrigation system and the data collected from the sensors will be used to automate and monitor the irrigation activities. This is ideal especially for places with water scarcity since the smart irrigation system decides the best time to perform irrigation activities, which is a tedious and time-consuming process to perform manually. Commonly found features in smart irrigation systems include the monitoring of soil and weather conditions. Extensive research was carried out to identify the aspects in which current smart irrigation systems were lacking and what could be done to improve them [1-3]. Besides creating a simple, affordable, and easy-to-implement smart irrigation system with the utilization of the Arduino Uno microcontroller which can be programmed to analyze data that is collected from sensors, this paper also aims to come up with improvements and additional functions that can optimize irrigation processes further based on findings from existing irrigation systems. The goal is to understand the existing technologies and what can be integrated into the system to enhance current irrigation systems [4-6]. In this work, using various sensors, microcontrollers, and cloud computing permit users to operate the irrigation system remotely through a user-friendly mobile application with an appealing user interface which most systems lack.

2. LITERATURE REVIEW

The literature on the use of microcontrollers in the Smart Irrigation Systems has been examined by many researchers to make the best system for the agricultural industry in the current modern

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era. It would be redundant to include all of the research's conclusions. Many sensors are recommended for the Smart Irrigation System, with the intention of reducing the cost of the irrigation system while effectively tackling the water wastage issue. It is discovered that most of the research done falls into a variety of areas, including the use of Arduino Uno, Wi-Fi, GSM Module, and microcontrollers [7-9]. These findings featured a component of Smart Irrigation Technology that makes use of a computer's and a mobile device's Bluetooth capabilities. A mobile device serves as the taskmaster, an Arduino microcontroller serves as the controller and a Bluetooth module serves as the command agent. The GSM Module is used to transfer text SMS data to a host server after receiving serial data from radiation monitoring equipment like survey meters and area monitors.

In these findings, two YL-69 soil moisture sensors were installed in various soil conditions coupled with LM393 comparator modules. Two electrodes make up the sensor YL-69. It gauges the amount of moisture in the area. The resistance of the soil to the current as it passes through the electrodes and across it yields information about the moisture content of the soil. More current will flow through the soil if there is more water present since the resistance will be lower. The moisture content of the soil is measured using a soil moisture sensor. Low level (0V) will be the digital output when the soil moisture value detected by the sensor is above the threshold value, and high level (5V) will be the digital output when it is below the threshold value. To determine whether the present soil moisture value is above the threshold or not, the digital pin is utilized to directly read the value [10-12]. With the use of a potentiometer, the threshold voltage can be controlled.

The function of a PH sensor is to measure the acidity or alkalinity of a water solution, which is based on the proportion of hydrogen (H+) or hydroxyl (OH-) ions in the solution. An acidic pH value is below 7, whereas a basic pH value is one that is above 7. Temperature-related changes in pH are possible in solutions. The DHT11 sensor is used to measure humidity and temperature. It measures the ambient air using a thermistor and a capacitive humidity sensor. This sensor is reasonably priced, uses little power, and allows for signal transmission up to 20 meters [13-15]. The PCB will convert the differential pressure trace that is measured by the differential pressure transmitter into a differential pressure signal, which can then be used for weather forecasting. It is a passive infrared sensor that uses variations in infrared light to identify motion. At a 15-degree angle, it can cover up to 10 meters. PIR responds to movements generated by items that emit heat and functions similarly to outdoor light with a motion detector. 1

The ATMEGA328P microcontroller is used to manage the on/off switching of the motor that can accommodate water sprinklers [17,18]. The Arduino transmits sensor data to the GSM-GPRS SIM900A modem. This modem receives a sim with a 3G data pack, which gives the system access to IoT functionalities. Values are then communicated over the modem to the IoT section. The GSM modem is a quad-band, plug-and-play SIM900A GSM modem with a high degree of flexibility for direct and simple integration with RS232 applications. Voice, SMS, Data/Fax, GPRS, and an integrated TCP/IP stack are supported. The tx and RX pins on an Arduino board are connected, respectively, to the RX and tx of a GSM modem.

The major goal of this smart irrigation system is to improve upon the current system by making it more creative, user-friendly, time-saving, and efficient. Measuring four variables, including pH levels, soil moisture, temperature, and humidity, the device also has an intruder detection system. Thanks to server improvements, farmers can now be informed of the state of their fields at any time. The sprinklers can be turned on and off by the system using the values collected by the sensors. The farm's irrigation system can be observed remotely by a farmer. As a result, the system helped create a smart farm. 2

3. METHODOLOGY

We have chosen to employ the use of various IoT devices and sensors in our smart irrigation system. The use of the sensors is prmarily to collect data to be processed and analyzed to determine whether the irrigation or intrusion detection system needs to be activated. The irrigation system will be set to activate when the moisture sensor detects the soil to be below a certain pre-determined threshold. This will be paired with other sensors such as the humidity sensor, temperature sensor, and rainfall sensor to provide a better and more effective way of watering the crops [19-21]. One implementation of such a system would be to collect data regarding the humidity and temperature of the surrounding, if it is determined to be humid and hot, it can be said that the soil moisture retention would be lower as the water would evaporate much quicker than in a cooler and less humid environment, therefore, additional water will be used to irrigate the crops and the soil to ensure the soil moisture level stays consistent and high for a longer period of time. This would allow the system to marginally save on power usage and water as it would require less usage of the sprinklers to water the crops by activating them less. Fig1 shows the water optimization prototype.

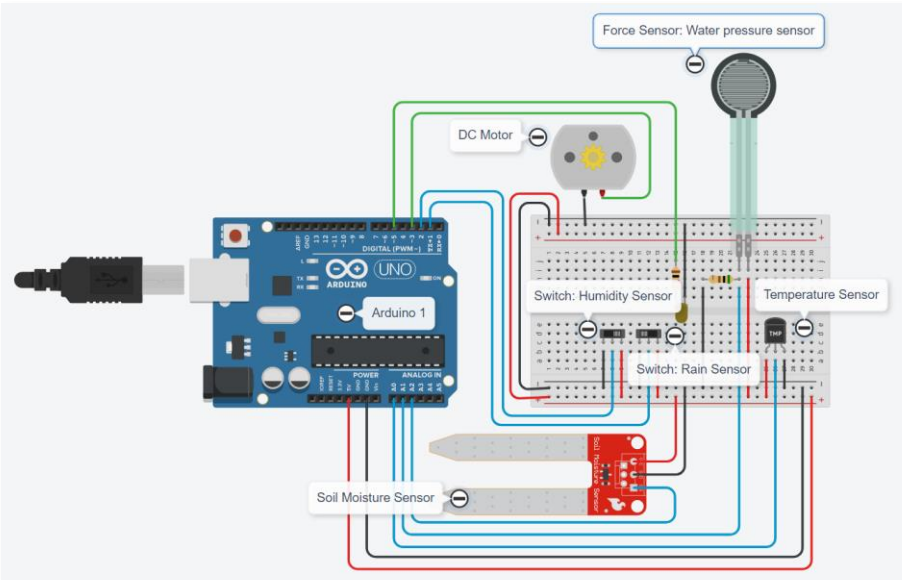

FIGURE 1. shows the Water Optimization Prototype

The above figure is the prototype used for water optimization, taking in the readings required that are mentioned above and following a set of steps to determine the best and most effective course of action. The following figure shows the code that is used to optimize the usage of the watering system, using the predetermined set of guidelines. Fig 2 shows the water optimization prototype codes.

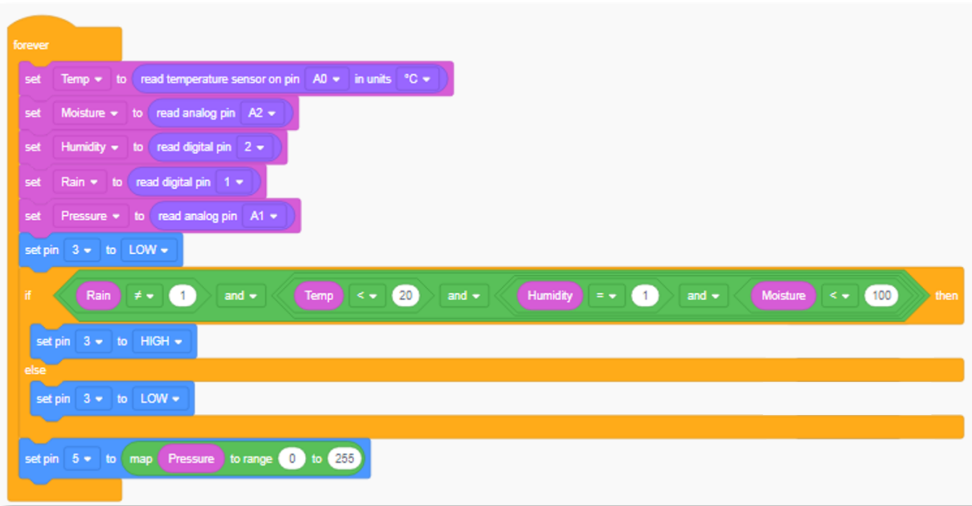

FIGURE 2. shows the Water Optimization Codes

Another implementation of IoT in our system would be the motion detectors. Through the use of motion detectors, the system can detect potential wildlife or people that are within the confines of the farm. Aside from the motion sensors, an infrared sensor could also be used to detect motion as well as to measure the heat radiated by the entity [22-24]. This would not only allow us to have more accurate readings on the presence of a pest but it is also used to determine whether the presence is a threat, as a motion detector could potentially detect the motion of an inanimate object that poses no threat. This information can be used to trigger safety mechanisms that would be used to ward off unwanted wildlife that could pose a threat to the safety and wellbeing of the crops. If the motion detectors sense a presence while it is activated, they could turn on lights as well as emit loud sounds to scare off unwanted wildlife. The lights that activate could be simple overhead lamps that are deployed across the farm, or it could make use of spotlights that are able to reposition and target the moving object to better identify the location of the object as well as increase the intensity of the light by targeting a specific spot rather than lighting up and the entire area. In addition to that, the piezo buzzer is used to emit beeps and sounds to alert employees that the motion detection system has been triggered, as well as be used as noise to ward off intruders. Fig 3 shows the Wild Animal Detection Prototype

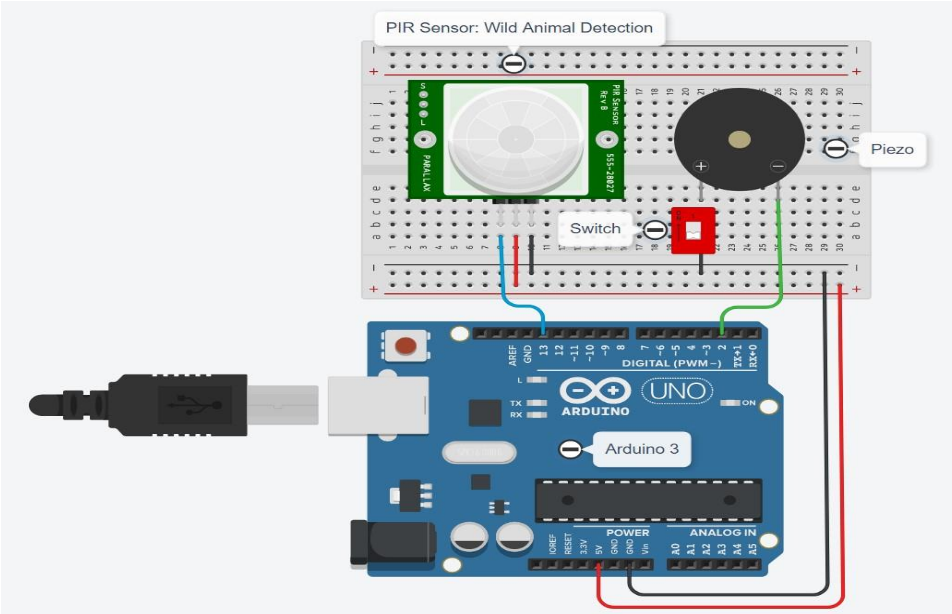

FIGURE 3. shows the Wild Animal Detection Prototype

The above figure is the prototype for the device that would be used to detect the presence and motion of any unwanted wildlife as well as the activation of the piezo buzzer if it is required according to the set of guidelines created for this system as shown in the code below. Fig 4 shows the Wild Animal Detection Codes.

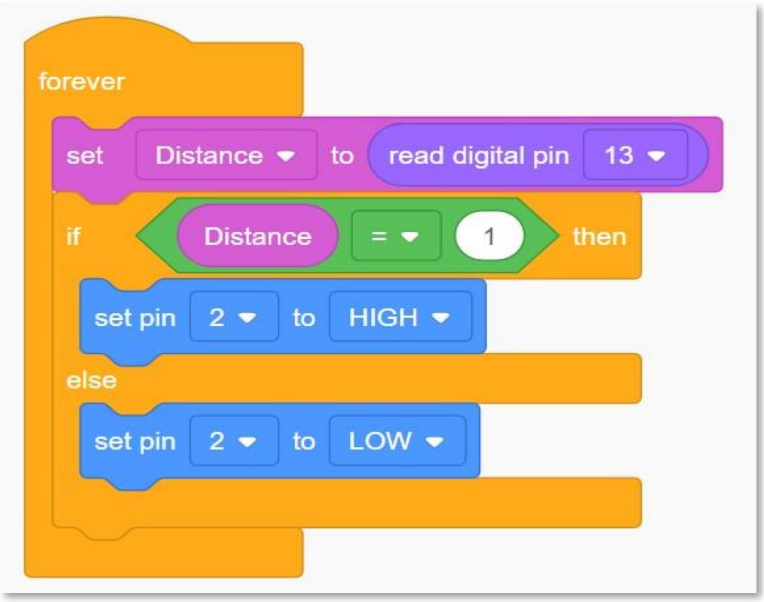

FIGURE 4. shows the Wild Animal Detection Codes

Aside from that, we have also implemented a water level monitoring system to help with the interoperability of the different IoT devices we have deployed [25-27]. This is to ensure that the user knows the amount of water that is left in their reservoir and alert them when it is running low. This makes it so that in the event that irrigation is required, there will be enough water to supply the sprinklers and irrigate the crops to the appropriate amount. This works by utilizing the ultrasonic distance sensor to measure the water level within a reservoir. If the water level is above a certain pre-set threshold and LED will light up green, and if the water level falls below that level it will show red. Fig 5 shows the Water Level Monitoring Prototype .

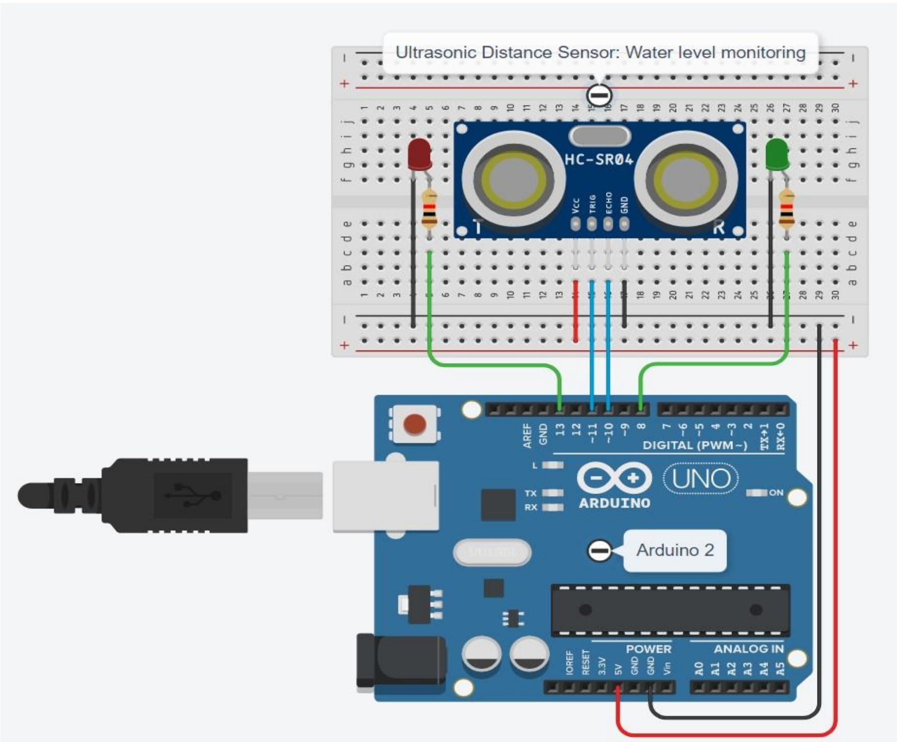

FIGURE 5. shows the Water Level Monitoring Prototype

The above figure shows the water level monitoring prototype, using an ultrasonic distance sensor to measure the water level. The following figure shows an example code where the water threshold is set to be 140 cm. Fig 6 shows the Water Level Monitoring Codes.

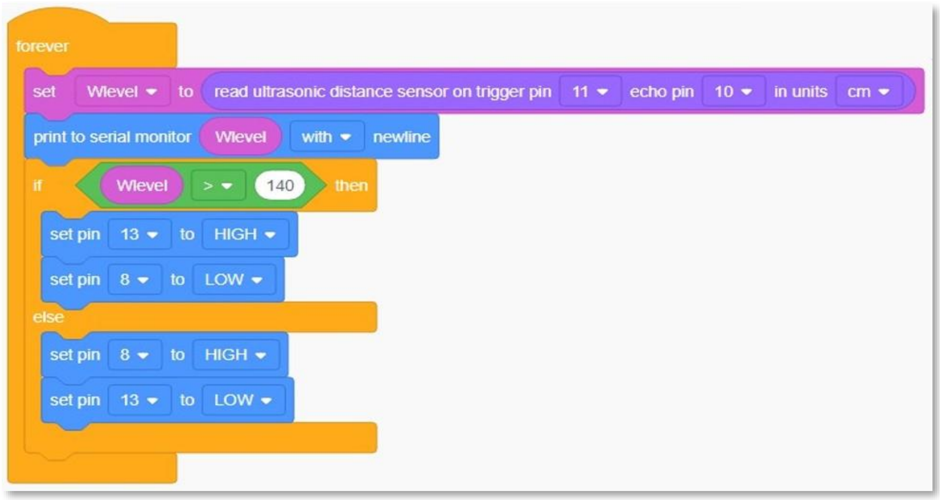

FIGURE 6 shows the Water Level Monitoring Codes

Another implementation in the out system is the use of a user authentication system. The system includes a login page that allows users to log in to their accounts and monitor the system from anywhere. This also acts to increase the level of security of the data that is being stored, preventing any potential tampering.

4. RESULTS AND FINDINGS

Research into smart irrigation systems has led to the understanding that for an efficient and effective smart irrigation system to be implemented, it should be able to monitor a few variables that could predict if the plants or crops require water. These variables are soil moisture, humidity, temperature, and rain. To be able to monitor this effectively and accurately, the smart irrigation system will have built-in sensors placed near the crops such as a soil moisture sensor, humidity sensor, temperature sensor, and rainfall sensor. As different crops require different needs, this would allow the system to gather data from the sensor and process it and only perform irrigation when it is required, hence preventing unnecessary over-usage of water and the risk of causing waterlogging [28-31]. To further enhance the user's knowledge of water optimization, the system will also come with a custom application that would inform the user of real-time data from the sensors, the amount of water used, and the amount of water saved compared to the previous day, and more. Additionally, a smart irrigation system should also be able to track the water level in the water reservoir since there is water scarcity, especially in rural areas where most agriculture is done. By doing this, the farmers or users could perform necessary precautions in case the water level in the reservoir crosses a certain threshold [32-34]. This will be possible since the system will include an ultrasonic sensor which would be installed at the top of the water reservoir facing the water. This would allow the sensor to sense how far the water is from the sensor, which could be used to make an accurate assumption about the water level. The user is indicated the water level by using two LEDs colored green and red each. The green LED will light up when the water level is above the threshold while the red LED will light up in case the water level goes below the threshold.

Another function that the proposed smart irrigation system that we included is the ability to detect wild animals and attempt to scare them away. Although it isn't necessary for an irrigation system, from the research we conducted, we found out that a huge percentage of crops planted are destroyed by wild animals and we wanted to propose a way to overcome this issue [35-37]. So we decided to detect the movement of wild animals near the crops using an infrared sensor that could sense animals with high accuracy even if the animal is hidden in the crops. This would then send a signal to the piezo which would start making loud noises in an attempt to try to scare away it without the need of hurting it. The user would also get a notification to their app if this happens so that they can handle it themself if needed.

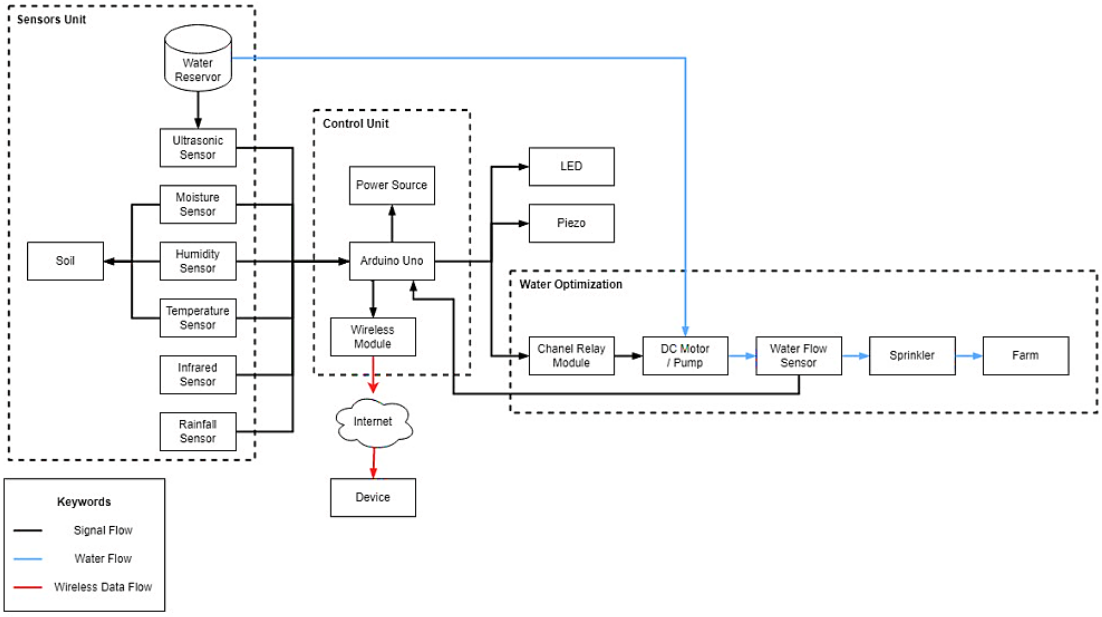

FIGURE 7. shows the Technical Diagram

Figure 7 shows the technical diagram displays a wider perspective of the proposed smart irrigation system. The proposed system is primarily separated into 3 different units, each of which plays a crucial part in the system. The first unit in the system is the control unit which only has three different components which are the Arduino Uno, the wireless module, and the power source. The control unit's primary function is to coordinate all the different components in the system and receive data from the sensor unit to process and perform the necessary task accordingly. The next unit in the system is the sensor unit which mainly consists of 6 unique sensors. The function of the sensor unit is to use the sensors to gather the required data and transfer it to the control unit to be processed. The final unit in the system is the water optimization unit which consists of a chanel relay module, dc motor, water flow sensor, and sprinklers. The function of the water optimization unit is to perform the irrigation if specific conditions are satisfied and the control unit supplies power to the dc motor to pump water from the water reservoir to the farm. Table 1 presents the main components.

TABLE 1 Main components

Column Header Goes Here	Column Header Goes Here
Arduino Uno R3	3
Temperature Sensor	1
Humidity Sensor	1
Rain Sensor	1
Soil Moisture Sensor	1
Water Pressure Sensor	1
Ultrasonic Distance Sensor	1

Infrared Sensor	1
DC Motor	1
Piezo	1
LED	3
Switch	1

Figure 1, 3, and 5 shows the prototype design for the proposed smart irrigation system which was made using tinkercad while table 1 shows the hardware required to assemble the system. Although the 3 parts of the prototypes could be built under the same Arduino Uno, we decided to split them into 3 parts to enable easier installation in larger locations without the need to have unnecessary long wirings running through the location. Figure 1, shows the prototype design for the water optimization unit which is in charge of when irrigation should take place. Next, figure 3 shows part of the prototype design for the wild animal/intruder detection system. Finally, Figure 5 shows the prototype design for the water level monitoring system.

5. DISCUSSION

The limitation of the proposed Smart Irrigation System from the design point of view is the proposed design is complex and sophisticated. To make sure the proposed system works as intended it requires hardware such as a soil moisture sensor, temperature sensor, humidity sensor, rain sensor, PIR sensor, water pressure sensor, ultrasonic distance sensor, piezo, a switch, 3 LEDs, and actuators. The number of the listed hardware will vary according to the need of the customers [38-40]. As the number of sensors increases, a proper connection between the sensors and the control module must be established to make sure the proposed system works as intended. Besides that, a lot of programming needs to be done to make sure the control module receives data from the connected sensors and sends instructions to piezo, LEDs, and actuators. From the proposed Smart Irrigation System's scalability and reliability point of view, Arduino Uno acts as a control unit in the proposed system and has a limited number of inputs. This limits the number of sensors that can be attached to a control unit module. At the same time as the sensors increase in a control unit module, the voltage required to power the sensors also will increase. If the sensors are not supplied with the required voltage, the sensors will malfunction. Thus, affecting the reliability of the proposed system. From the cost point of view, the proposed system will be expensive to maintain as the scale of the system being implemented on a farm increases. Currently, for a larger-scale implementation of the proposed system control unit modules are being used to overcome the number of input limitations. As the number of control modules increases, the number of components to be maintained also will increase [41-44]. This will increase the maintenance cost on top of the cost to maintain the machine learning model. Besides that, additional funds also will need to be invested to make sure the control modules are communicating seamlessly with each other.

6. Conclusion and future work

In conclusion, this paper has introduced enhanced monitoring strategies to improve efficiency in water activities. Our proposed smart irrigation system was able to achieve the objective of introducing an automated irrigation system with enhanced functions using IoT. The data that is collected from numerous sensors used in our system is vital to schedule watering activities and alert users in case of any situation that requires attention. This stands out from conventional irrigation methods since the irrigation system is switched on and off manually by users, modern irrigation methods that switch on the irrigation system at a fixed time without analyzing the optimal time for irrigation activities, or existing smart irrigation methods that only analyze weather and soil conditions but lack functions such as deterring animals that could damage the crops or defective components in the system that could cause water wastage leading to costly losses or requiring routine check-ups to identify if there are any faults in the system. Numerous ideas were brought up and discussed amongst our group and extensive research was done carefully deciding which ideas to incorporate into our smart irrigation system. There is still room for improvement for the proposed Smart Irrigation System to make it accessible for every farmer. The improvement will be focused on two different perspectives. The first perspective will be to resolve the current limitations of the system and the second perspective will be updating the system to be future-proof.

From the first perspective, a "plug and use" feature will be introduced to the system. This new feature will make the system to be intelligent as it can automatically detect the sensors and preset the programming for the sensors. With this new feature, there will be no need to code each connected sensor with the control module to make sure the control module detects the sensor and processes the data from the sensor manually a programmer. Besides that, this new feature will encourage the "Do It Yourself" method as farmers can identify faulty sensors via the fault detection system and attempt to resolve them. This will indirectly reduce the maintenance cost as users do not need to pay technicians to fix an issue. Secondly, the traditional sensors will be replaced using wireless sensors. By replacing the sensors with wireless sensors, the sensors will be connected to the control unit via the existing network that facilitates the cloud function. This will eliminate the need of using several control unit modules to connect sensors that are placed far from a control unit and long wiring to connect the sensor to the control unit. Next, an appropriate control module that can be scaled more easily will be identified. Farmers can quickly scale up their smart irrigation system by simply adding features and attaching sensors to the control module if they have the right control module, as opposed to having to buy a new smart irrigation system. Every farmer can utilize the proposed method because its cost can be brought down, and it is simpler and more scalable. From the second perspective, it may be assumed that many people would utilize smart agriculture systems in the future because the proposed smart irrigation system is a component of smart agriculture. The suggested system will be designed to be readily incorporated with other smart agriculture systems to account for that. Farmers will benefit financially from this since they can easily convert their present farms to smart farms utilizing the suggested technology.

Following that, the proposed system can be retrofitted with pumps and sensors to facilitate irrigations that are being conducted in hilly terrain. One of the main objectives of proposing this smart irrigation system is to reduce water wastage that is occurring in agriculture. Implementing this feature will have a positive impact on achieving the objective, as more water will be wasted in irrigating hilly terrain as water need to be transported to hilly terrain and this system can address the issue.

Finally, this system can be updated to accommodate irrigation via drones. Using drones for irrigation will reduce the irrigation time needed to irrigate the crops as drones can fly over a large area in a brief time and irrigate the crops from the sky. Besides that, this will reduce water wastage as the irrigation process will be done in a controlled manner. Farmer's burden also can be reduced by deploying automated drones to irrigate the crops.

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