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IoT Based Approach for Smart Irrigation System Suited to Multiple Crop Cultivation

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Abstract

India has always been an agriculture-dependent nation. This paper proposes an advanced automated irrigation approach suited to Indian cultivation practices. Heretofore, the proposed systems and research work were focused on single crop cultivation, whereas the Indian farmers follow multi-crop cultivation. This paper is structured upon Indian agriculture system and Indian weather conditions. This model applies the technology of the Internet of Things and Data Science to implement real-time analytics of the collected data. Multiple sensors are deployed in the field to create an on-field dataset into the cloud system. The cloud system scraps the required data from the meteorological center and compares it with the on-field data set. The analysis is then done using the concepts of data science to determine the amount of water to be released according to each crop type in the field. The proposed system is highly efficient and economically feasible. The system also provides a mobile application which helps the farmer to track the developments occurring throughout the field.

Keywords: IoT, Data Science, Automation, Agriculture, Irrigation, Multiple Cropping.

1. INTRODUCTION

Internet of things is a technology that enables the automation of various devices and the real-time analysis of the data collected through/for these devices [1]. Due to its enhanced data collection capability, the integration of the system and their accuracy is increased significantly. It employs various sensors for the data collection procedures. The analysis of the collected data can be done through the use of Data science. Data science is the approach which makes use of predictive and prescriptive analysis to get useful information out of data [2]. It uses a quantitative approach to achieve accurate decisions and precise results.

Currently, agriculture accounts for about 18% of the country's GDP (Gross Domestic Product), and about 54% of the total workforce of the country is still employed in the agriculture sector [3]. With time, most technologies in our country have grown and developed further, including Agriculture. But in most parts of India, the methods used for agriculture are primitive even in this era. Hence, there is a necessity to transform and evolve the traditional methods being used for farming and other agricultural activities in India. The development in the field of agriculture (or this field) needs to be focused primarily on water usage. Water is the most important resource for the growth and development of any crop. During the lifecycle of the crop, water has a great influence on each phase [4]. Either the short or excessive supply of water can negatively harm each phase. Water also affects the quality and harvest of the crop. Various problems such as a decrease in the availability of nutrients, waterlogging, a decrease in productivity and salt imbalance can occur due to improper supply of water. Hence, it becomes important to control the water supply to ensure proper development of the crop.

Many Indian farmers employ the concept of multiple cropping in their fields to maximize their use of available land and also to ensure the proper yield of the crops. To implement a multi-crop system, the water supply needs to be very efficiently delivered. In this paper, we assume that a field is divided into sections to grow various crops together. Crops of different varieties are sown in each section of the field. An on-Field module which comprises of sensors and the automated valve is installed at every section. Field-modules are connected to the master router through Wi-Fi modules.

The concepts of the Internet of Things are used in the proposed system to collect on-field data from each field module (using sensors installed). This collected data is then sent to the cloud system through the master router. In a cloud system, collection and integration of data are performed to form the on-field data set. This data set is then compared with other datasets within the cloud system. Using concepts of Data Science, data is analyzed to derive optimum values for water requirement suited for each field. These values are then stored in another database through which the optimum values are further sent to the digital pump and the automated valve accordingly through the master router. The automated valve is given the instruction about the actual amount of water to be supplied to the field. Master Router coordinates with the automated valves to turn them on and off so that the optimum amount of water is supplied to the fields.

2. LITERATURE REVIEW

Research Paper [5] proposes a system which will help a farmer to make decisions using real-time information being generated regarding the field and the associated crops. Multiple cropping practices enhance productivity in agriculture especially in regions with a limited area of operation. Multi cropping enables the farmer to perform efficient farming by limiting resource usage and also providing crop support through companion crops [6]. Implementation of the Penman-Monteith and Pan

Evaporation Method for the analysis and computation of water requirement for various crops during various stages has been done [7]. Real-time field analytics can be carried through the use of sensor networks to control irrigation in the field in a manner that the crop yield is maximized and water usage is minimized [8].

Researchers [9] have proven that water usage is reduced when an automated irrigation system that relies on soil moisture as a parameter is implemented. A customized sensor-based system can be used which reduces the power consumption as well as the cost incurred during the irrigation process [10]. Researcher [11] showed the effective use of wireless communication to achieve smart irrigation and sensing system to enable smart farming. The microcontroller board, Arduino which has been proven to be power efficient and compact is used for the system [12]. GSM mobile network is used to operate an irrigation control system for efficient use of water and electricity [13]. But GSM is limited in its data transfer rates, so it needs a Wi-Fi module for transfer of data throughout the system. Wireless sensor network and GPRS module have been used to build an automated irrigation system by the researchers [14]. A sensor-based system for a smart irrigation system can be expanded easily without losing the primary organization [15]. For automatic irrigation in rural areas, robotic systems are deployed in the fields [16].

Heretofore, the research work done related to automated irrigation using modern technologies had various drawbacks which prevented them from being adequately implemented in the Indian agricultural scenario.

3. EXPERIMENTAL SETUP

The Field shown in Fig. 1 is divided into a number of sections. These sections are created to incorporate the technique of multiple crop cultivation. The on-field module is planted at every section of the field.

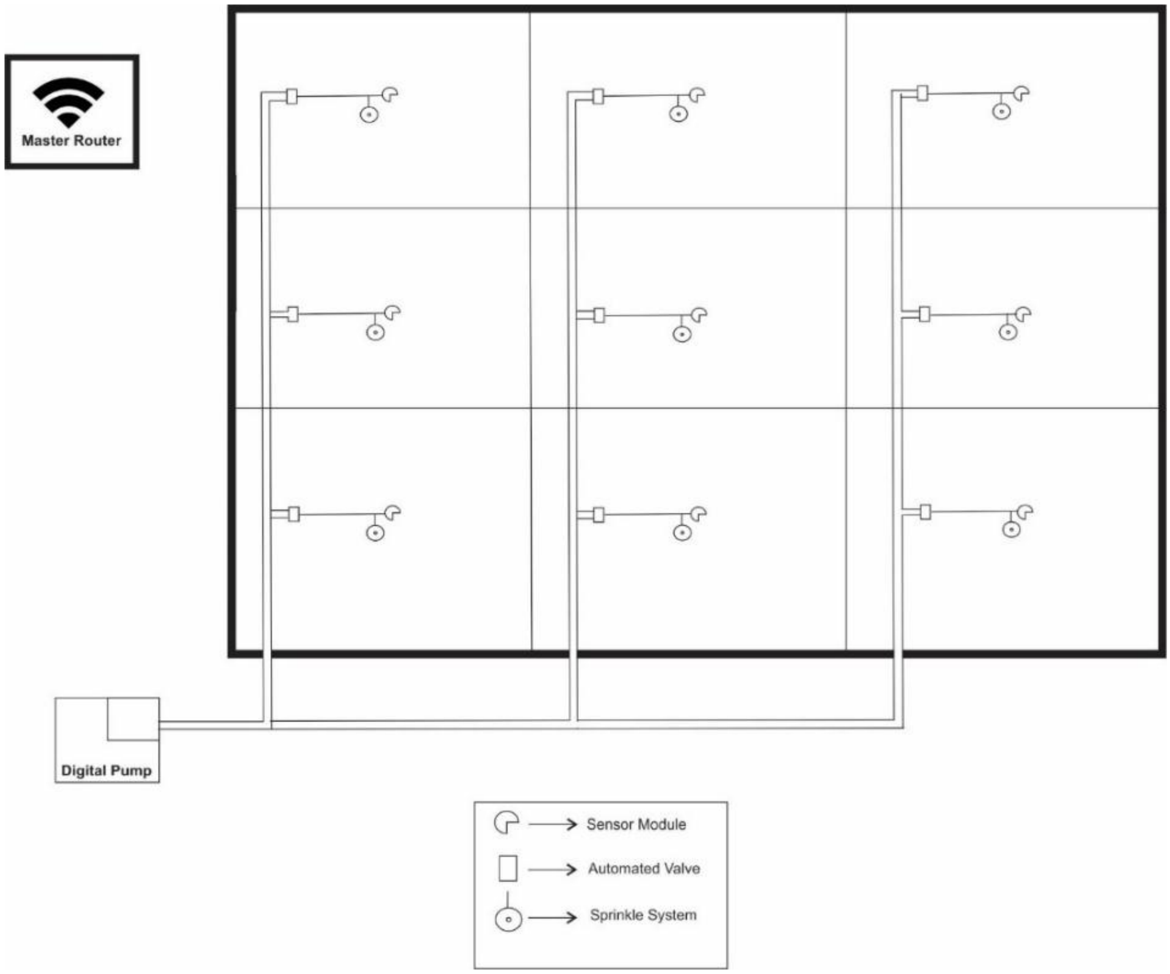

Fig. 1. Experimental Setup with Deployment of On-Field Sensors.

A digital pump, which is fitted with the water storage tank, releases water through pipe arrangement connected to every section of the field. The digital pump distributes water through a sprinkler present at every section. The On-Field module controls these sprinklers. A static IP is assigned to the cloud system. The master router identifies the cloud system [17] and can communicate with it via the static IP. The pump module and on-field module are connected to the master router.

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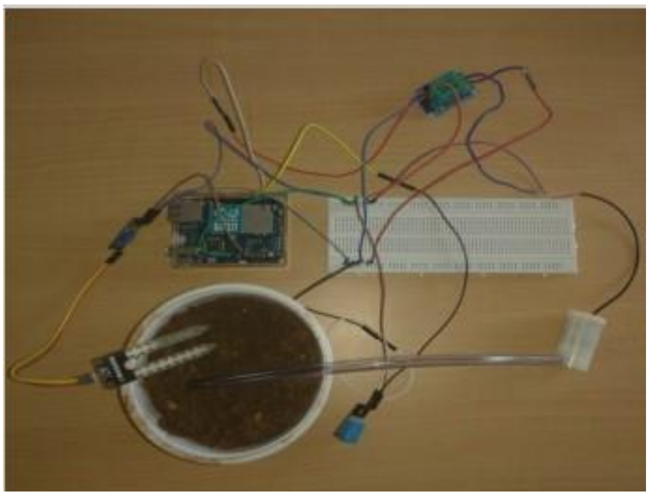

Fig. 2. Simulation of On-Field Module.

3.1. On-Field Module

The On-Field module comprises of following components:

- Arduino Uno
- Sensors (FC-28, TMP-36)
- Wi-Fi module (ESP8266)
- Automated Valve

The Arduino Uno is an open source micro-controller [18] which serves as the housing and control unit for generating inputs and outputs for the connected components (Both digital and analog). Sensors comprise of FC-28 (Humidity sensor) and TMP-36 (Temperature sensor) which are connected to micro-controller through analog pins (A0) and (A1) respectively [19]. ESP8266 (Wi-Fi module) is connected to micro-controller through communication pin (TX and RX). Automated valve is being controlled with the digital pin of the Arduino Uno.

3.2. Pump Module

The pump module comprises of following components:

- Arduino Uno
- Wi-Fi module (ESP8266)
- Digital pump

The TX pin of ESP8266 (Wi-Fi module) is connected to RX pin of Arduino Uno and vice-versa. The Digital Pump is being controlled with the digital pin of the Arduino Uno.

4. WORKING

The field taken into consideration is distributed into a number of sections. A variety of crops are sown in each section of the field. The On-Field module transmits data regarding parameters like humidity and temperature to the Arduino Uno. Arduino Uno transmits the collected On-field data from the sensor module to cloud through the master router. On-field Database is formed from collected data.

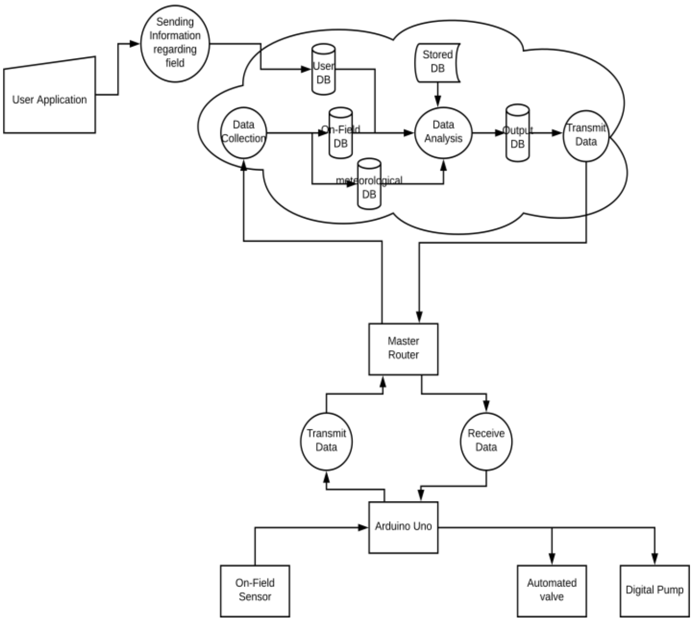

Fig. 3. Overview of Proposed System.

User database is formed from the data entered into the application that is being provided to the user (farmer). Also, a database is derived from previous research work [17]. Meteorological database is retrieved from the nearest Meteorological center.

Table 1. Detailed Description of Databases of Proposed System.

Name	Function	Attributes
User Database	This is created when the user inputs the required data into the provided application.	Day, Field number and Crop type.
On-Field Database	This is created by the data that has been transmitted by the on-field Sensor module.	Temperature, Humidity of the corresponding field.
Meteorological Database	This is retrieved from the nearest meteorological center.	Evaporation rate, water rise (in mm), temperature.
Stored Database	This is a predefined database that has been created from the work of previous research paper. [17]	Crop type, Initial stage, Intermediate stage, Final stage.
Output Database	This is created after the analysis and computation have been completed.	Field number, Water released.

4.1. Mobile Application

The User first starts the application and logs in. The user then gets the option to selects the field number and then to fill in the associated crop that has been planted in that section of the field. Once all the data is fed to the application, the data is transmitted to the cloud system where the User Database is created. The user is then directed to a new screen wherein the required amount of water, which is released by the system, is displayed. The current conditions screen includes the information about the sensed parameters (i.e., humidity, temperature and the age of the crop) of the current day and the subsequent day as shown in Fig. 4.

Fig. 4. Mobile Application Screenshot (Current Conditions).

The Home screen displays the total amount of water that is released in the entire field, the field numbers and the associated crops with them and the current days' conditions, i.e., humidity, temperature and the age of the crop.

4.2. Data Analysis

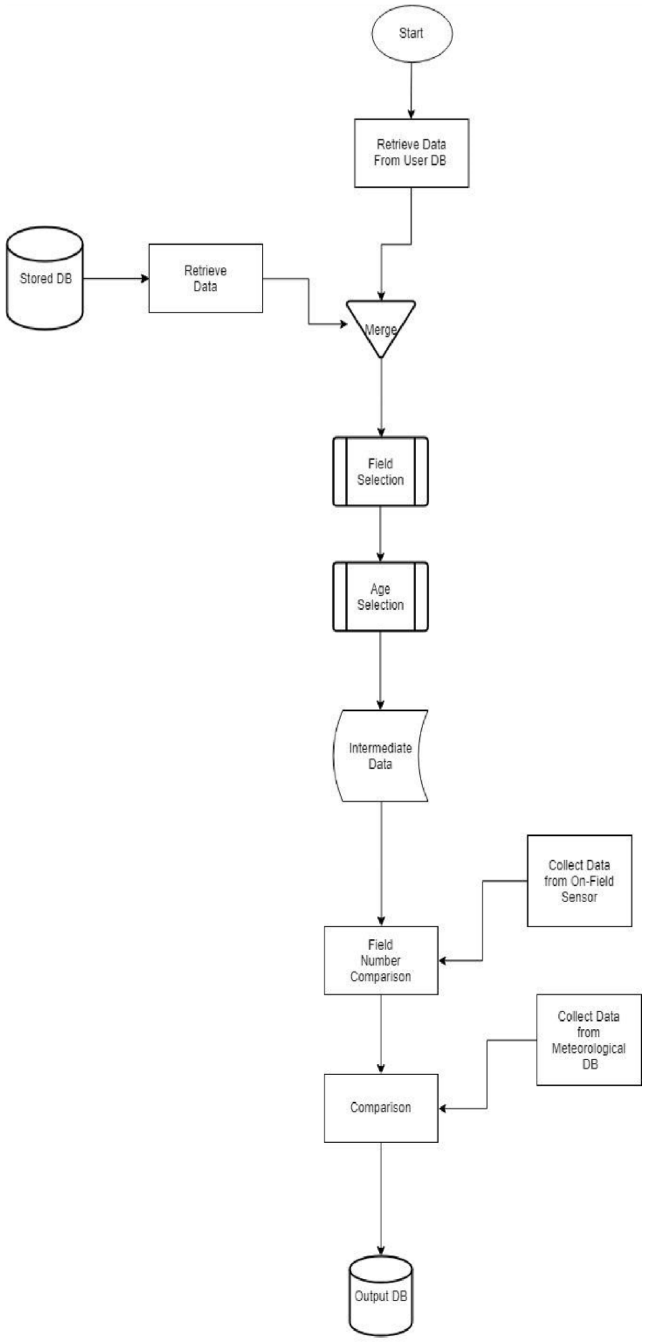

Fig. 5. Diagram of Data Analysis.

Fig. 5 depicts the data analysis performed in the cloud system which starts with the retrieval of the data from the user Database. Parallelly, data is retrieved from the stored Database and merged with the user database. Then the field selection process shown in Fig. 6 followed by age selection process (Fig.7) is performed which leads to the formation of intermediate data.

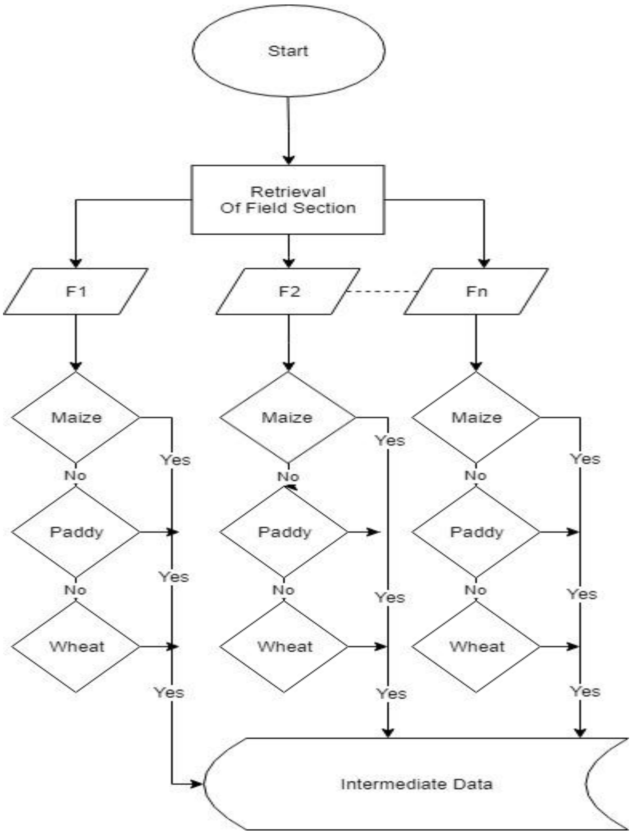

Fig. 6. Field Selection Process.

The field selection process begins with the retrieval of the consequent field numbers. Now for each field, parallelly, a selection control mechanism is put into use. This mechanism produces an intermediate data which constitutes of field sections with associated crop type with them.

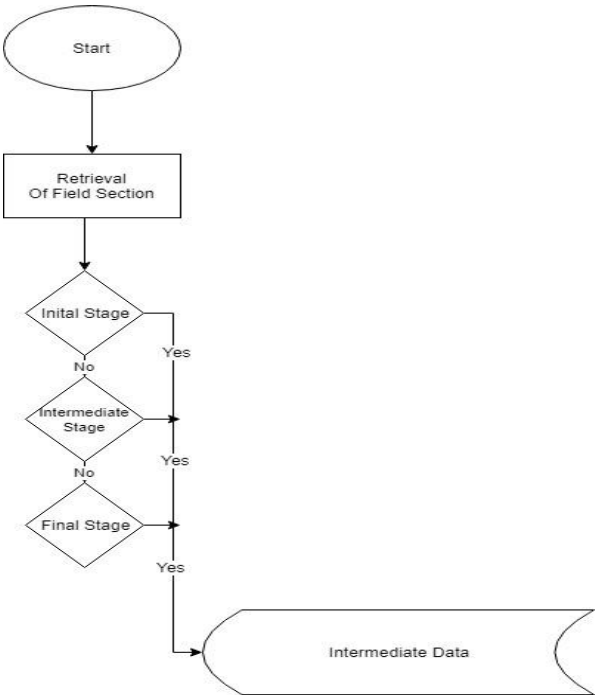

Fig. 7. Age Selection Process.

Once the field selection mechanism is complete, the age selection mechanism begins. Here, a decision mechanism is put to use which uses the age of the crop to determine the total amount of water required at each section of the field and these values are stored in the intermediate data. Finally, the intermediate data constitutes the required total amount of water to be needed in the respective sections of the field.

The collected data from the On-field sensor constitutes the present moisture level at each section of the field. This data is then compared with the intermediate data that has been produced earlier in order to state the amount of water to be released in the field. For example, 50 units of water are required for the crop at the present age, and currently, the field constitutes 30 units of water then 20 units of water is needed to be released.

The collected data from the meteorological database contains the various climatic parameters like evaporation rate and/or the precipitation on the following day. So, alterations in water requirements have to be done in such a way that it neutralizes the water loss due to evaporation and/or increase in water due to precipitation. For example, the former optimum value of water requirement was 20 units and say if evaporation causes loss of 5 units of water, then 25 units of water are supposed to be released. Or say if precipitation would cause 10 units of increase in water then 15 units of water is supposed to be released. After all the comparison and decision-making mechanisms finish execution, we get a final optimum value of water requirement for respective field sections. This data is stored in the output database and is transmitted to Arduino Uno through the master router.

Arduino Uno commands the digital pump about the total water requirement in the field. Once, the digital pump starts to release the water then at every half of a second, the on-field sensor transmits the updated value of water in each field section. This updated value is then subtracted from the total water requirement value to decide whether to continue releasing the water or to turn off the current valve. Once all the valves are turned off, then the digital pump is turned off as well.

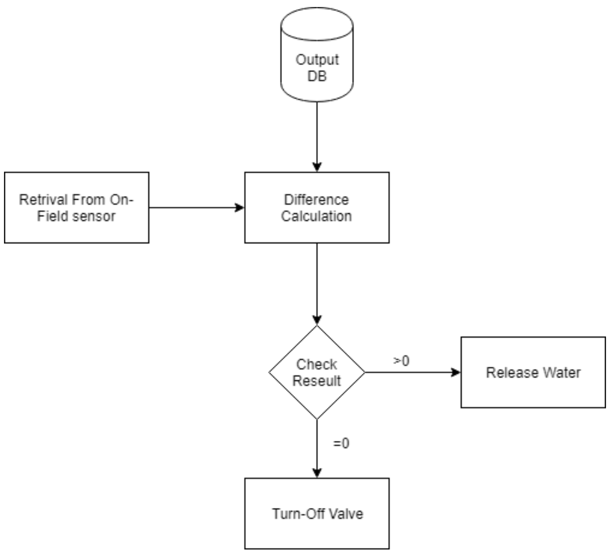

Fig. 8. Difference Calculation Process for Water Requirement.

5. RESULT AND DISCUSSION

Different crops require different amounts of water at different ages. The data are given in the paper [7] was used in order to obtain the following table: -

Table 2. Water Requirement in mm.

Crop	Initial Stage	Intermediate Stage	Final Stage
Rice	146.60	286.80	192.90
Maize	42.75	225.90	360.30
Wheat	24.10	27.80	127.20

This table represents the water requirements of crops at various stages in their life cycles. The water requirements of these crops were analyzed with meteorological and other datasets to obtain the final optimum values of water requirement.

These values are displayed along with the weather conditions through an application interface provided to the user (farmer) so that the user can track the developments throughout the field.

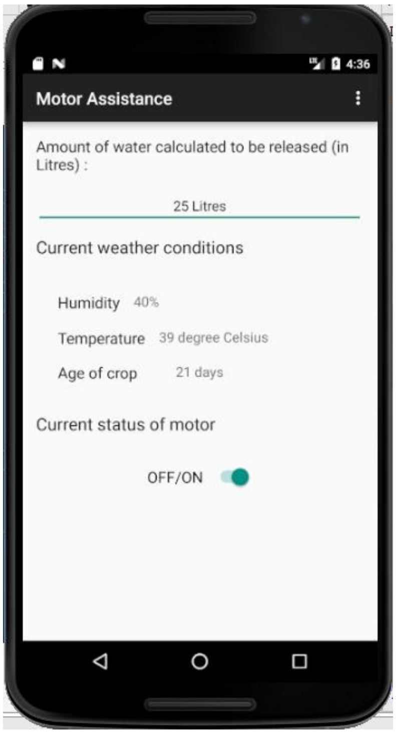

Fig. 9. Mobile Application Screenshot (Home Page).

6. CONCLUSION

In India, the irrigation system that is being put to use is primitive in nature. It requires a comprehensive knowledge of the field as well as the weather conditions to efficiently irrigate the field. But this type of knowledge and experience are not necessarily readily available to an average farmer. Hence many farmers of India struggle with this process. So, there is a need for an automated irrigation system to enable efficient and effective irrigation in multiple cropping systems which offer benefits in the sense that they provide enhanced productivity especially in regions where the area is limited [6]. Multiple cropping not only improves the yield from a limited space available but also increases the crop production and provides better soil utilization. Also, it helps to control weeds and maintain the soil fertility.

The approach to an automated irrigation system has been demonstrated. Here, the field has been assumed to have multiple sections for incorporating multiple crop cultivation. Each section of the field is equipped with a sensor module which is a collection of various sensors that measure various parameters like soil moisture and temperature about a particular field section. This data is then sent to the cloud system through the use of a master router to form a dataset. Another dataset is obtained from previous research works which contain the details regarding the stage of a crop and the corresponding water requirement for the crop at that stage. Further data is also obtained from the meteorological center. All the datasets are then put through the data analysis process incorporating the concept of data science. This analyzed data is then transmitted to Arduino Uno via the master router to command the digital pump about the total water requirement in the field. Real-time comparisons of the field conditions are performed to decide whether to continue releasing water or not. Once the water requirements are met, the automated valves are turned off followed by the digital pump. Hence this approach provides an efficient solution to the modern-day irrigation requirements suited to the Indian agricultural scenario.

7. FUTURE WORK

Though the pesticides and fertilizers have their individual uses in the agricultural field, if these are put in excess, they can cause harm to the soil, crops, and environment. Thus, controlled amounts of these could be deployed in a proper manner. Further work could also be done in the field of nutrient management for the soil. Parameters apart from moisture and temperature can be taken into consideration in order to increase the efficiency of the system. The farmers can be provided with information about the ideal crop combinations for the multiple cropping scenarios in order to ensure low costs and higher production.

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