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Design and Development of Soil Moisture Based Automatic Irrigation System in Nepal

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Abstract

A prototype soil moisture based an automated irrigation system were developed at National Maize Research Program in 2018 to study the water requirement of drought tolerant crop genotype. The irrigation system has been controlled by Arduino UNO as a micro controller. The instant soil moisture data were collected either in Excel format or graphical format using internet of things through the programming of Global System for Mobile Communication: Subscriber Identity Module (GSM:SIM card) of Nepal Telecom. The developed automated irrigation system has found maintained the predetermined threshold soil moisture. This automated irrigation system has been developed to make applicable for drip irrigation system which has operated at low water pressure maintained by 1.5" professional-grade solenoid valve. The introduction of this automated irrigation system has developed the base for Nepalese agricultural scientist in designing and promoting irrigation technology to make Nepalese agricultural more sustainable, mechanized and productive.

Introduction

The global risk perception survey, that has conducted among the 900 recognized experts of the world economic forum had reported that in next 10 year the highest level of societal impact will be from water crises (World-Economic-Forum, 2015). The extensive unmanaged use of surface water and drastic withdraw of ground water making imbalance on natural resources. Agriculture is the mainstay of the economy accounting for one third of the gross domestic product (GDP) in Nepal where irrigation water management plays vital role in water crises. On the other hand the rapid population growth has put significant pressure on Nepal's natural resources (von Westarp et al., 2004). In this way challenges to feed rapidly growing Nepalese

populations of 28.825 million (CBS, 2017) had put the pressure to change the way of traditional cultivation practices with new innovative, motivated and highly productive agriculture techniques. von Westarp et al., (2004), had evoked that the access to irrigation water is one of the critical components for meeting the food security of rapidly growing population. Lack of infrastructure for water storage and irrigation system in Nepal is one of the major constraint to harvest runoff from the large rivers often occurs by flooding events, causes insufficient water for farming (S. Nepal et al., 2019). If the farmers could get access to irrigation, there are possibilities to intensify their crop rotations up to three crops per year to meet the raising food demand (Nepal et al., 1996). Thus, development of high efficient irrigation technology is the best ways to boost the productivity of dry-land farming system. In traditional irrigation method usually more water is required even for lower production also drastically reduce yield because of inappropriate amount of water used for irrigation (Shuhbam et al., 2018). Shyam et al., (2015), had mentioned that as compare to other sectors agriculture sector have not been made advancements with significant technology specially for irrigation system which need to monitor on a regular basis. He further justified that farmers generally do not monitored the soil moisture content or if monitored it generally observed manually which are prone to errors and hence mislead in proper irrigation management.

Automated irrigation system is an electronic machine associated with a combination of various software and hardware based irrigation system in which agriculture land is irrigated automatically by the system, based on pre-defined instruction set by operator. Information and communication technology (ICT) can help the advancement of agriculture in many ways. As said above the traditional way of agricultural practices is no longer sufficient for the growing world. In this context, digitalization of agriculture information is necessary in playing vital role to make remote accessible of the information for its quick monitoring and management (Piya, 2012). Automatic microcontroller based irrigation system save a large quantity of irrigation water because the irrigation take place only when there will be intense requirement of water (Suresh et al., 2014). Introduction of GSM based automatic irrigation control system in the automatic microcontroller, could send soil moisture information in a regular basis and android app is been used a means of methodology to monitor efficient use of water resources (Karan et al., 2015). In this way, irrigation management can be improved with the application of automatic watering systems also with the help of such kind of system a farmer can monitor his field status from any part of the world (Guru et al., 2017). Micro irrigation system can optimize water productivity for agricultural crops. This kind of irrigation system can distribute wireless or wire connected soil-moisture sensors placed in the root zone of the crops. Further, sensor information could be triggers actuators, and transmits data to a web application. Finally, an algorithm developed with threshold values of soil moisture could control irrigation water quantity with programmed microcontroller based gateway (Birasa, 2016). Furrow irrigation or surface flooding which is one of the simplest and most ancient irrigation methods is the dominated irrigation method in Nepal (Biswas, 1989). This ancient method of irrigation can be improve for water use efficiency depending on the proper irrigation scheduling (Jha et al., 2017). Application of automatic irrigation system with such type of irrigation method will helps to maintain the proper irrigation scheduling and will improve irrigation efficiency as desired to produce optimal yield.

Thus, the objective of this project were to develop a prototype automated irrigation control system which can play important role in determining the precise amount of water, requirement to cultivate the pipeline maize genotype. It not only provides comfort but also makes the irrigation more efficient and save precious water resources. Thus the developed technology can save time and energy of Nepalese farmers in making their agriculture more advanced, efficient and productive. This article will provide a reference to agriculture researcher in developing such innovative, practical and environmentally friendly smart irrigation technology in low cost that can be affordable by Nepalese farmers.

Methods

Brief Information of Research Station

The innovative technological adoptive research was conducted at National Maize Research Program (27°39' N, 84°20' E and 186 m altitude) of Nepal Agricultural Research Council (NARC), located at Rampur, in Chitwan district of Nepal. The research station is well facilitated with irrigation system, where the inlet of the newly developed automated irrigation system was connected to the overhead tank having sufficient stored water and continuous electric supplies were maintained throughout the crop season. The subtropical humid climate has dominant the research station with cool winter and hot summer. Average annual precipitation is 2215 mm with a distinct monsoon having more than 75% of its annual rainfall from Mid-June to mid-September (NMRP, 2017); (Upadhyay et al., 2016).

The soil of research station is acidic (pH 4.6-5.7) having light texture and sandy loam. This experimental research station is only one governmental research organization under NARC, which has key responsibilities to develop new genotype of maize for the nation and reduce the yield gap of maize cultivation between research station and farmers field. This research development at this station has been carried out to determine the exact amount of water required to cultivate newly developed maize genotype before it would be promoted to Nepalese farmers.

Working Mechanism

An automatic irrigation system consists of two soil moisture sensor (described below in section 2.3.1), buried in the field to monitor its instant soil moisture condition. The soil moisture sensor connected to microcontroller provides the input data for the microcontroller where as the threshold value fixed by potentiometer define as circuit breaker to flow the current for the operation of solenoid valve. The current continued flowing to keep the solenoid valve “on” until the soil moisture detected by soil moisture sensor attained the threshold value.

Technical Details

Soil moisture sensor

The soil moisture sensor (SMS) measure soil moisture grades that change in electrical conductivity of the earth (soil resistance increase with drought). The electrical resistance is measured between the two electrodes of the sensor. A comparator activates a digital output when adjustment threshold is exceeded. Each sensor consists of a thermocouple that is connected to a LED circuit. When water is introduced due to the following exothermic reaction, the circuit breaks. This is denoted by a green LED light (binary 0). Counter- wise, if the reactions are not strong enough to send the voltage required to break the circuit, the LED glows red (binary 1). These signals are relayed using GSM modem and ZIGBEE protocol to the motor which consists of receiver, transmitter and relay signal processor. Then processor deploys water required per grid according to this analysis. The typical soil moisture sensor used in this project is shown in figure.1.



Figure.1 Soil moisture sensor in operation

Solenoid valve

A solenoid valve is an electromechanical operated valve, which has used to regulate the fluid. The mechanism of solenoid valve used in this system (Figure 2) works on the principle of linear action, plunger-type actuators to pivoted-armature actuators and rocker actuators. The solenoid valve is connected with 12 volt relay and 24 volt AC supply (Figure 2). The movable contact of relay is connected with positive terminal of 24v AC supply , the negative terminal of 24v AC supply is connected to negative terminal of solenoid valve & the normally close (NC) of relay is connected with positive terminal of solenoid valve.



Figure 2. Solenoid Valve connected with power supply installed at site

Arduino Board

The Arduino UNO is a widely used open-source microcontroller board based on the ATmega328P microcontroller. Microcontroller is programmed in such a way that it receives the input signal from the sensing material which consist of a comparator to know the varying conditions of the moisture in the soil. The board is equipped with the sets of digital and analog input/output (I/O) pins that may be interfaced to various expansions boards (shields) and other circuits. The board features 14 Digital pins, 6 Analog pins a 16 MHz ceramic resonator, a USB connection, a power Jack, and ICSP beader, and a reset button. To get started, simply connect it to a computer with a USB cable or power it with AC-to-DC adapter.

The Arduino is connected to LCD display as shown in Figure 3 (a). We used just 6 digital input pins from the Arduino board. The LCDs registers from D4 to D7 has been connected to Arduino's digital pins from 4 to 7. The enable pin has been connected to pin no 12 and the RS pin has connected to pin no 11. The R/W pin has been connected to ground and the V0 pin has connected to the potentiometer.

The Arduino is connected with two moisture sensor both VCC pin of moisture sensor is connected to 5V pin of Arduino (Figure 3b), A0 pin of moisture sensor is connected to A1 pin of Arduino, and both GND pin of moisture sensor is connected to GND pin of Arduino.

The Arduino is connected with potentiometer (Figure 3a). The VCC pin of potentiometer is connected to 5 V pin of Arduino, the signal pin of potentiometer is connected to A2 pin of Arduino and GND pin of potentiometer is connected to GND pin of Arduino.

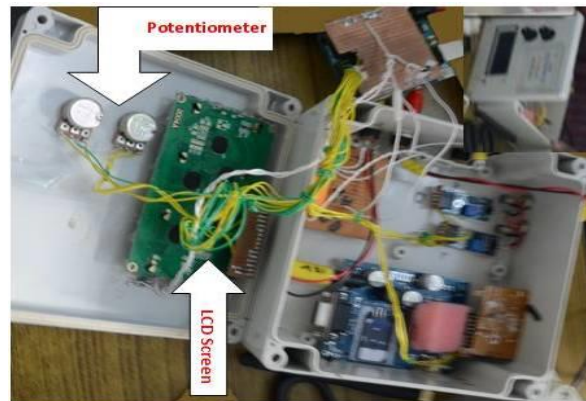


Figure.3 (a) The Arduino connected with LCD and potentiometer

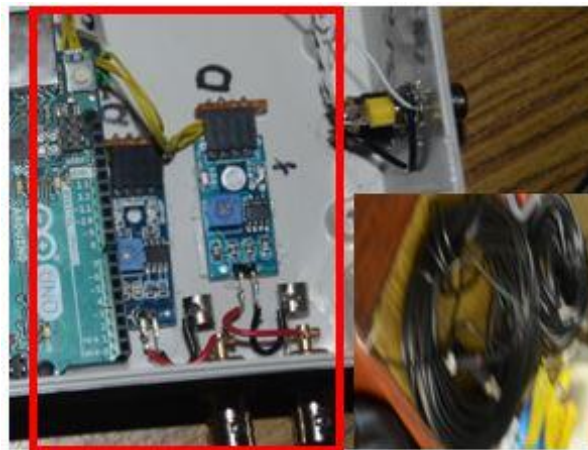


Figure.3 (b) The Arduino connected with soil moisture sensor

GSM Modem

Modem stand for modulator demodulator which is used as a communication device to modulate an analog carrier signal with digital and transmit at the same time it also demodulates the incoming modulated signal to extract the analog information (Thakali, 2007). The Arduino is connected to GSM module with adapter as shown in Figure 4. The Arduino pin no 9 is connected to RXD of GSM module, the Arduino pin no 10 is connected to TXD of GSM module, the Arduino GND is connected with GND of GSM module and negative of 12 V DC adapters, the VCC of GSM module is connected to positive of 12 V DC adapter.

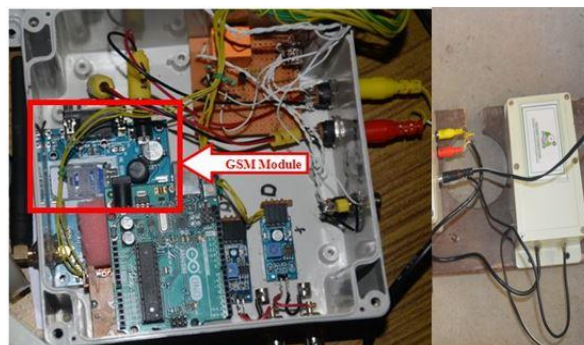


Figure.4 The Arduino connected to GSM module with adapter

Relay and Transistor

The Arduino is connected with 12 V relay, 12V DC adapter and PN2222A transistor, all final assemble connection as shown in Figure 5. The Arduino pin no 13 is connected to base of the transistor, the emitter is connected to negative 12V DC adapter, the collector is connected to negative part of coil termina, and the positive part of the coil terminal of relay is connected to positive of 12V DC adapter.



Figure.5 The assemble of automatic irrigation control system along with adaptor and soil moisture sensor

Automation and Control System

Automation of farm activities such as irrigation has transform agricultural domain from being manual and static to intelligent with dynamic leading to higher production with lesser human supervision (Rawal, 2017). Arduino UNO having TMEGA328 as microcontroller has been used to automatized irrigation system which monitor and maintains the desired soil moisture via automatic watering. Thing Speak is an open data platform and API for the Internet of Things (IOT) that enables to collect, store, analyzed, visualized and act on data from sensors or actuators, such as Arduino. IOT has been used to keeps updated about the status of irrigation. The information from the sensors is regularly transmitted to webpage through Thing Speak Channel using GSM-GPRS NTC SIM modem for direct and easy integration to RS232 applications. A NTC SIM with 3G data pack is kept into the modem that provide IOT features to the system.

Results and Discussion

In order to implement the observation pattern a real-time performance of web application has been programmed. The tests were carried out to quantitatively assess real-time soil moisture data acquisition and instruction sending process. The result shows that the average delay of the data acquisition process was 12 seconds, and the real-time performance has meet the needs of the equipment control and irrigation decision making. The system is accessed through internet 3G modem communication networks and the control software system in internet of things which has improved the real-time performance.

Programming and Software Design

To make the irrigation research easier, precise and innovative the automatic plant watering system has been created. The Arduino UNO consisting Tmega328 Microcontroller is introduced in this technology. It is programmed in such a way that it sense the moisture level of the field soil and supply the water as soon as it goes below the threshold value set by potentiometer (Ojha et al., 2016). The software has programmed in the Arduino UNO Tmega328 Microcontroller.

The channels created in Thing Speak webpage with the channel named “National Maize Research Program Automatic Irrigation System (NMRPAIS)” with date and time is shown in the figure. 6.

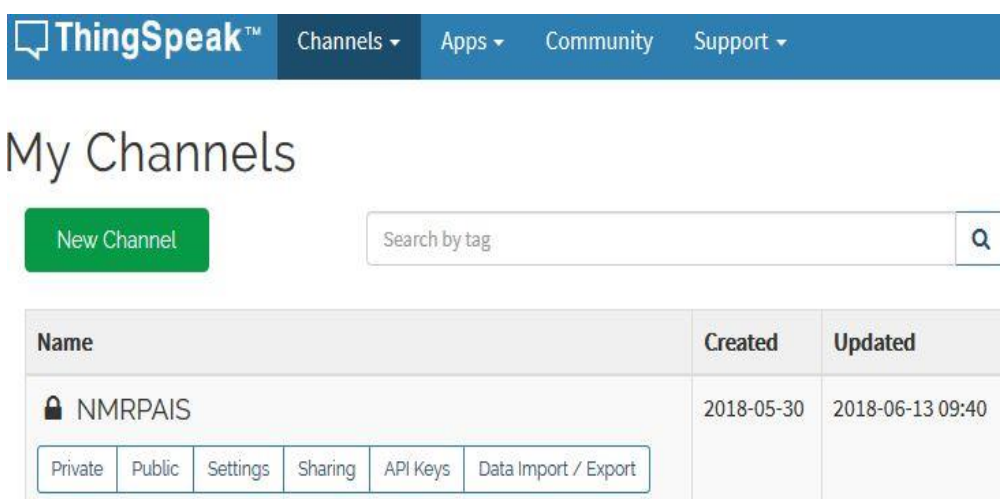


Figure. 6 Channels named NMRPAIS created in Thing Speak webpage

Soil Moisture Monitoring

This automatic irrigation system consists of two real time sensing soil moisture sensor as described above which create an automated irrigation mechanism. The soil moisture sensors buried into the soil measure the volumetric water content of field soil. It measures the volumetric water content in reference to electrical resistance, dielectric constant that interacts with neutrons as proxy for the instant moisture content. When the field soil moisture level found below the threshold value the moisture sensor send the signal to the Arduino board which triggers the solenoid valve to turn on and supply the water till the moisture level reaches the threshold value. Thus the functionality of the entire system has been tested throughout and the output data received from the IOT for soil moisture are show in the figure 7. Karim et al., (2017) has presented similar alert system for the control of water stress of plants using IOT technology. Nagarajapandian et al., (2015) has intended to create an automated irrigation mechanism which turns the pumping motor on and off on detecting the dampness content of the earth. In this way the feed data received from the soil moisture sensor is exported from the Thing Speak channel as show in Table 1. In the table, ‘Field 1’ value represents the threshold value set in the potentiometer whereas ‘Field 2’ and ‘Field 3’ value represent the soil moisture of soil moisture sensor 1 and 2 respectively at corresponding date and time.

Table 1. Feed data received from the ThingSpeak channel for two soil moisture sensor and threshold value

<i>created_at</i>	<i>entry_id</i>	<i>field1</i>	<i>field2</i>	<i>field3</i>
2018-05-31 05:59:02 UTC	1	80	94	100
2018-05-31 06:07:46 UTC	2	80	89	95
2018-05-31 06:16:30 UTC	3	80	81	87
2018-05-31 08:07:18 UTC	4	85	93	94
2018-05-31 08:58:46 UTC	5	85	97	98

2018-05-31 10:01:38 UTC	6	85	100	97
2018-05-31 10:15:37 UTC	7	85	97	93
2018-05-31 10:24:20 UTC	8	85	92	90
2018-05-31 11:06:16 UTC	9	85	89	89
2018-05-31 11:21:59 UTC	10	85	96	90
2018-05-31 12:11:26 UTC	11	85	95	88
2018-05-31 12:29:06 UTC	12	85	100	93

It has found that both sensors perform well and the system has maintained the threshold value of soil moisture at 50% soil water content. Both soil moisture sensor graph shows that the irrigation has did automatic at threshold soil moisture value and is the successful demonstration carried out at National Maize Research Program, Rampur, Chitwan.

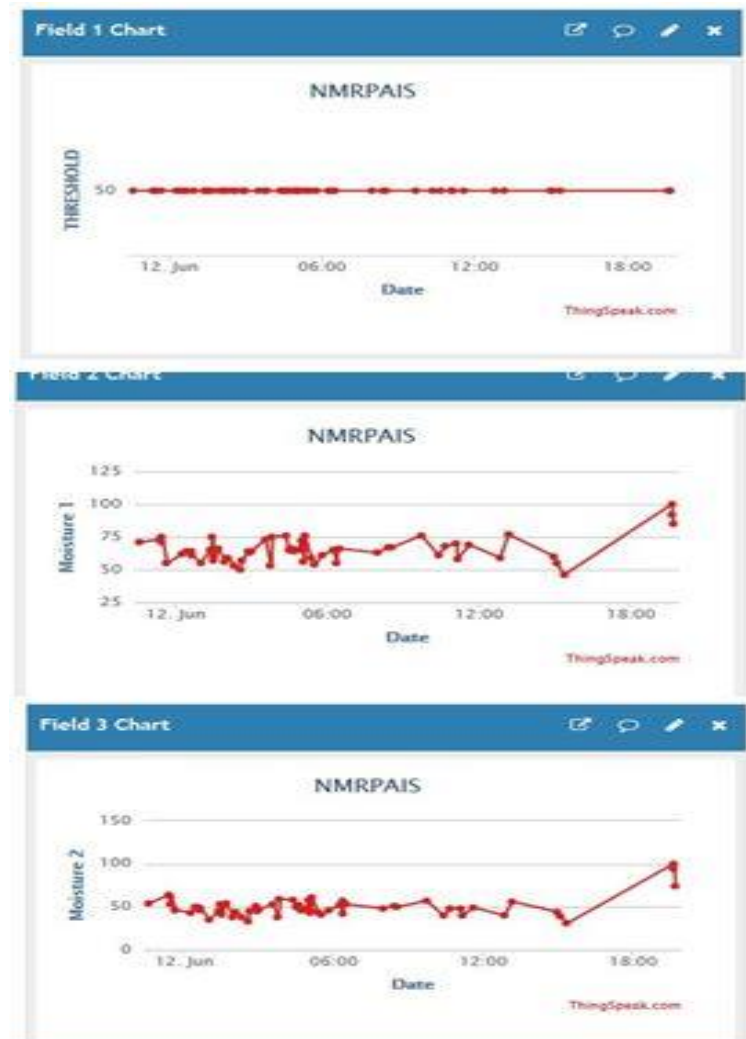


Figure. 7 Soil moisture monitoring data exported from Thing Speak

Data Transformation

The feed data from sensor processed by microcontroller stored and get transferred through IOT and stored in ThingSpeak Channel created with the name NMRPAIS which can be exported either in excel format or in graphical form as shown in figure 7. The exported data for soil moisture may analyzed or verified with the manual method obtaining the soil moisture from the field as Gravitational Method. Analysis of the exported data is required to know either the soil moisture sensor is sending the real-time data or not and also do the field had irrigated at threshold value or not. Sometime the rust in the soil moisture sensor obstacle in sending the feed data which can be seen in feed data transferred should found helpful in monitoring timely.

Economics of Irrigation System

This automatic system has been designed and demonstrated as pilot project based on agriculture research purpose and hence had not made cost analysis for large scale production. The tentative expenditure for its design and installation is found to be about USD \$1000 which is very much affordable for general farmer or gardener. The water use efficiency is needed to be estimated for its further economical analysis in long term sustainable.

Conclusion

This GSM based automated irrigation system has been first time demonstrated in Nepal at National Maize Research Program, Rampur Chitwan, Nepal. The system has designed and demonstrated to monitor the soil moisture in drought tolerant maize genotype has found successful in monitoring and controlling the soil moisture of experimental field soil. The system keeps the soil moisture at threshold level set for the potentiometer in GSM modulator. This allows the solenoid valves to flow water if the soil moisture content in the field sense by soil moisture sensor goes below the threshold value and restrict the water flow as soon as soil moisture sensor attains the threshold value. The feed data from the soil moisture sensor transferred to the ThingSpeak channel as internet of things (IOT). These feed data are easily exportable either in excel or graphical format. The real time soil moisture of field can be monitored through the ThingSpeak channel with NMRPAIS user login has been created.

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