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Smart Farming—A Prototype for Field Monitoring and Automation in Agriculture

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***Abstract*—The agricultural productivity of India is gradually declining due to destruction of crops by various natural calamities and the crop rotation process being affected by irregular climate patterns. Also, the interest and efforts put by farmers lessen as they grow old which forces them to sell their agricultural lands, which automatically affects the production of agricultural crops and dairy products. This paper mainly focuses on the ways by which we can protect the crops during an unavoidable natural disaster and implement technology induced smart agro-environment, which can help the farmer manage large fields with less effort. Three common issues faced during agricultural practice are shearing furrows in case of excess rain or flood, manual watering of plants and security against animal grazing. This paper provides a solution for these problems by helping farmer monitor and control various activities through his mobile via GSM and DTMF technology in which data is transmitted from various sensors placed in the agricultural field to the controller and the status of the agricultural parameters are notified to the farmer using which he can take decisions accordingly. The main advantage of this system is that it is semi-automated i.e. the decision is made by the farmer instead of fully automated decision that results in precision agriculture. It also overcomes the existing traditional practices that require high money investment, energy, labour and time.**

***Index Terms*—Agriculture, Arduino IDE, Automation, Sensor.**

I. Introduction

Agriculture plays an important role in Indian economy of about 58% of the rural households depending on the principle means of sustenance [1]. It involves several laborious and time consuming tasks such as manual watering of plants, shearing furrows in case of excess rain or flood and preventing animal grazing. These activities are the most fundamental and essential things that is ought to be carried out with a high degree of accuracy, precision and efficiency. Moreover, inefficient use of available resources results in diminishing the quality and production of the crops thus imbalance the environment.

Automation in agriculture makes farmers work with ease. Automated systems with sensors provide promising solutions to farmers so that they can monitor and carry out the agro activities. There are many existing techniques proposed in the literature that uses automated systems involving computers, data base technologies [1–6]. But the need for the hour is an inexpensive and simple solution to farmers for controlling the field.

The proposed solution for the above mentioned problems is an autonomous system consisting of a master controller along with the required sensors. The system is designed in such a way that it monitors the field and aids the farmer in managing the agro-related activities. The sensors may a vital role in the autonomous functioning of the system. Soil Moisture Sensor, with an ability to find the extent of moisture content and pH balance in the soil up-to ten meters circumference depth, determines the moisture in soil and classifies it as dry or wet soil. Float Sensor helps in identifying the level of water in the field and triggers the controller to pave way for excess water to run down to nearby well and settle down in underground water-table. The presence of Infra Red (IR) sensor is to detect the animal intervention within the field and safeguard the crops.

These sensors are configured and attached to the microcontroller i.e., ARDUINO which manages the activities based on the output of the sensors. The real time data conveyed to the controller by the sensors will ensure smooth and successful operation. Arduino is pre-programmed [5], which directs the output based on sensors input to promote precision agriculture. Major advantage with this device is that, albeit the device is autonomous, the final decision is made by the farmer itself. This is made practical by means of Global Systems for Mobile communication (GSM) Module and Dual Tone Multi Frequency (DTMF) Module.

The voltage from digital circuit will neither be sufficient to run the sprinkler nor to run the motor to move the plate, levee. Hence, relays are introduced to remove this ambiguity. This device will primarily be used in sandy soils with high infiltration rates, irrigating the crops such as maize, ragi etc. which requires less water to sustain. The advantages of choosing the proposed device over the existing methods are:

i. Automated and require minimal human effort.
ii. Environment friendly.
iii. Accurate and reliable in its operation.
iv. Fairly easy to maintain
v. Precision Agriculture.

The paper is organized as follows: Section II describes the prototype requirements and Section III illustrates the overall architecture of the prototype. In Sections IV and V, hardware and software implementation details are explained. Section VI summarizes the results obtained and Section VII concludes the paper.

II. Prototype Requirements

Agricultural automation system consists of interlaced components that are in a type of integrated system that has a set of distinctive properties and virtues. According to [5], the following are the properties:

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Future proof: The system should be developed with latest technology and ensure easy upgradability.

Cost Efficient: The system should be designed with the lowest cost possible while ensuring adequate efficiency. Our proposed system includes a higher number of sensing and actuating substances that is needed to be in an undisturbed communication with each other and with the central entity.

Configuration with Minimum effort: The configuration of the system should be time-efficient and simple. In addition to that new modules or functions to the system should be performed by a model that is similar to plug-and-play.

Seamless Connection: All the parameters of the system are ought to be connected, either via a specialized one that allows merging various technologies or through affiliated interface. The outside world connectivity is also a desired functionality.

Interaction with Users: The users should not be asked for random or repetitive commands. The interface must have familiar controls that need limited or no training even for an inexperienced user.

Security Purpose: The prototype must be conscious and protect its users from threats like illegitimate access, privacy violation or eradication.

III. Overall Solution Architecture

The proposed prototype consists of a number of subsystems that allow it to operate effectively. The purpose and functionality of the various modules indicated in the figures are given below:

A. Soil Moisture Sensor

Soil moisture sensors measure the chemical analysis of water content in the soil since the direct quantitative ionic measurement of soil moisture requires expelling, dehydrating, and weighting of a sample. Soil moisture sensors measure the volumetric water-ion content indirectly by using certain parameters of the soil, like dielectric constant, electrical resistance or neutron interaction, as an alternate for the moisture content of soil.

Soil moisture module is super sensitive to the atmospheric humidity and it is generally used to ascertain the moisture content of the soil. The output of the sensor is HIGH at normal state that is at the threshold value or below, and goes low when the soil humidness exceeds a threshold value. This digital output signals are sent to Arduino directly to detect the variation in the moistness of the soil. Similarly, analog output of the sensor can also be connected to microcontroller to detect the moisture level.

B. Float Sensor

Float sensors ranges from large to small in size and may be as simple as a mercury switch buried in a hooked float or as complex as a series of optical or conductance sensors producing diverse outputs as the fluid reaches various different levels within the sub-system. It is an electrical ON/OFF switch that is self-regulating when liquid level shifts up or down with respect to the described level. The signal thus available from the float sensor can be exploited for the control of an allied electrical element like solenoid, lamps, and relays etc. or a motor pump.

Float sensors contain sealed nib switch in the stem and a permanent magnet in the float. As the float rises or falls with the level of liquid the nib switch is activated by the permanent magnet in the float. It is also applicable in normally opened, normally closed and change over contact form.

C. IR Sensor

An Infra-Red (IR) sensor is an electronic device which is used to sense the attributes of its surroundings by either transmitting and/or exposing IR radiation. IR sensors are also capable of measuring the heat being transmitted by an object and detecting its motion.

All the substances that have a temperature higher than absolute zero (0 K) possess thermal energy and are sources of IR radiation. It also includes blackbody radiators, tungsten lamps and silicon carbide. IR sensors generally use IR lasers and LEDs with particular IR wavelengths as sources. These sensors work by using a particular light sensor to detect a selected light wavelength in the IR spectrum. An LED which produces light at the same wavelength as required by the sensor is required. When a substance is nearer to the sensor, the light emitted from the LED bounces off the object and into the light sensor. A transmission medium is required for IR transmission, which consists of either a vacuum or air or an optical fiber.

D. Arduino UNO

Arduino UNO is a controller board based on the ATmega328P [5]. It consists of 14 digital input/output (I/O) pins (among which 6 can be used as Pulse Width Modulation outputs), 6 analog input pins, a 16 MHz quartz crystal, a USB connector, a power jack, an In-Circuit Serial Programming header and a reset button. Arduino UNO can be linked to a computer with a USB connector and powered-up using an AC-to-DC adapter or battery to get started.

The Arduino UNO is programmed with the Arduino Software (IDE) . In Arduino UNO the ATmega328 is pre-programmed with a boot loader which permits the user to burn the new code to it without the use of an external hardware programmer module. It is communicated using an original STK500 protocol. The Arduino UNO board can be powered-up through an USB connector or with an external power supply in which it is selected automatically. External (non-USB) power can be supplied either from an AC-to-DC adapter (wall-wart) or from battery. The ATmega328 has 2 kB of Static Random Access Memory (SRAM) and 1 kB of EEPROM (that can be both read and written with the EEPROM library) and it also has 32 kB (with 0.5 kB occupied by the boot loader).

E. SIM 900A GSM Module

GSM Module is a SIM900 Quad-band Geo-Synchronizing device that works in the range of various frequencies like 850 MHz, 900 MHz, 1800 MHz and 1900 MHz. Its size is very compact and it is easy to use as a plug in GSM Modem. This modem is configured with 3 V and 5 V DC TTL interfacing circuitry, that allows the users to interface directly with 5 V microcontrollers (AVR, Arduino, 8051 controller, PIC etc.) as well as 3 V microcontrollers (ARM Cortex XX, ARM etc.) . The baud rate of the device can be configurable in the range of 9600–115 200 bits per second through Attention (AT) commands. This Modem has internal TCP/IP stack that enables the users to establish connection with internet via GPRS feature. It is suitable for SMS as well as data transfer application in peer-to-peer interface. This modem can be interfaced using Universal Synchronous Asynchronous Receiver and Transmitter (USART) feature with a microcontroller.

GSM Module is controlled by microcontroller through SIM900 AT Commands Set. The command set consists of several commands, which performs activities such as sending and receiving messages, GPRS support, TCPIP application, SIMCOM, etc.

F. DTMF Module

DTMF decoder consists of MT8870 chip, with 3.5 mm jack and audio cable. This decoder circuit arrangement determines the dial tone from the mobile and decodes the key that is pressed. For the DTMF signal frequency detection, a touch tone decoder called IC MT8870 is used. The IC decodes the DTMF input (i.e., the key pressed by the user) to 4 digital outputs. The IC MT8870 decoder circuit uses a technique that involves digital counting principle to determine the tone frequencies and to verify that these frequencies correspond to standard DTMF frequencies. The DTMF tone is a form of one way communication between the dialer and the mobile exchange in which the whole communication consists of the touch tone initiator and the tone decoder.

The DTMF signals can also be transferred directly from the microphone pin of the mobile in which the signals from microphone are processed by the DTMF decoder. These signals generate an equivalent binary sequence and these outputs are used for many sensible applications.

G. Mechanical Parts for Levee

A rack and pinion is a type of linear actuator that consists of a pair of gears and a straight track with matching saw tooth arrangement with gears. The circular saw tooth gears convert rotatory motion into linear motion with the help of DC motor attached to it. “The pinion” is a circular gear that has teeth on a linear bar called “the rack”. The rotational motion applied to the pinion causes the rack to move relative to it in which a movable plate is fitted to the rack, thereby translating its rotational motion into linear motion. This arrangement is used for the movement of plate at the end of levee that protects the crop field from floods or heavy rain. Foam sheet, which is light weight as well as inexpensive, is used as the covering part at the edge of embankment.

This mechanical arrangement is moved by means of DC motor. Two 60 rpm 12 V DC motor geared motors are used at the alternate edges. This is a light weight motor, which produces 2 kgcm torque, with no-load current of 60 mA (max) and load current of 300 mA (max) .

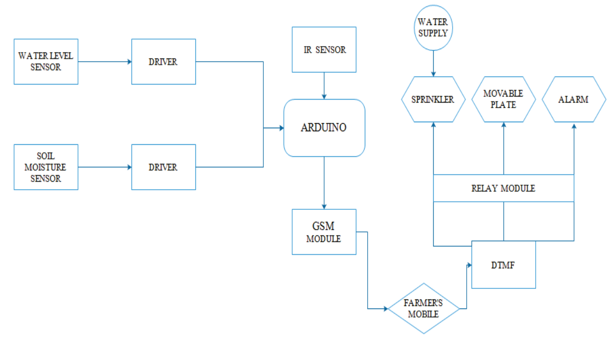

Fig. 1. Block diagram of the proposed prototype.

H. Solenoid Valve and Batteries

A solenoid valve is an electro-mechanical device which is used for controlling the gaseous substance or liquids. It is controlled by an external electrical current that runs through a coil. When the coil is energized, a magnetic field is created, which causes the plunger (shutter) to move inside the coil. Depending on the design of the valve, the shutter will either open or close the valve. When the external electrical current is removed from the coil, the valve will return to its de-energized state. The main task of solenoid valves is to shut off, dose, release, distribute or mix fluids. Solenoid valves offer fast and safe switching of shutter, highly reliable, extended service life, good medium compatibility of the materials used, low control power and the design is compact.

The choice of battery for this prototype is lead acid. Though heavier, they have a high capacity and are less expensive than lithium ion batteries. In addition, they are quite safe are less liable to explode in case of overcharging or manhandling. This is extremely important as it reduces the cost and improves the safety of the device. The cells are configured to produce 12 V when fully charged with a capacity of approximately 1.2 Ah.

IV. Hardware Implementation

The overall flow diagram of the proposed prototype is shown in Fig. 1.

Major hardware parts to be constructed in the prototype involve the formation of movable plate at the levee edges and placement of all the sensors at the right place to bring out accurate results. The plate used to cover the end of the levee should be stronger, eco-friendly and also should be inexpensive and hence the right choice is foam sheet. Depending upon the size of the field and levee, the foam sheet is cut and made used at the end of levee. Here, for the field of size (15 feet $*$ 10 feet), foam sheet of size ($1^{1/2}$ feet $*$ 1 feet) is used at the alternate edges of the field.

These foam sheets are fitted inside the rack-and-pinion so that these can be easily controlled and moved by a motor. Motor used here is 12 V DC, 60 rpm motor which is quite sufficient to sustain the friction in the sand and move the plates

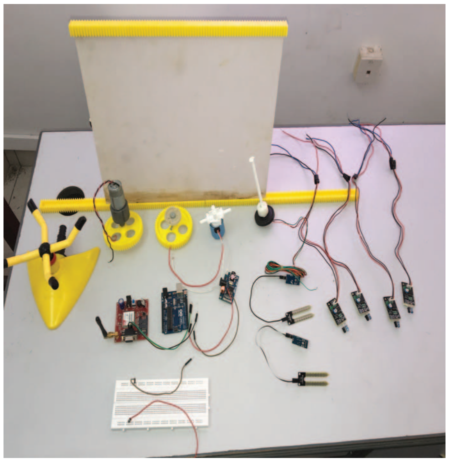

Fig. 2. Hardware component requirements for the prototype.

whenever required. In order to get accurate results, sensors placement is very important. Soil moisture sensors should neither be placed too closed nor too wider. Equal spacing of about five feet should be made between two soil moisture sensors. Float sensors should be kept along the edge of levee for the better results. IR sensors should cover the outer portion just after the levee is formed so that it can trigger the controller in the case of animal intervention. Devices such as Arduino, GSM Module and DTMF Module are placed separately away from the field in a water resistant box as only the sensors are required to be arranged in the field. The hardware components used in this prototype is shown in Fig. 2.

V. Software Implementation

The ATmega328P microcontroller in ARDUINO UNO was programmed and debugged in Arduino Uno Software IDE version 1.6.4. The Arduino allows easy programming while maintaining a high level of flexibility in terms of functions to be performed.

A. *Algorithm*

i. Define all the input pins and the output pins of the Arduino, with input being soil moisture sensors, float sensor and infrared sensors, and output being sprinkler, motor and alarm.
ii. Define the serial communication between GSM Module and Arduino with AT Commands.
iii. Monitor the status of all the sensors continuously and initiate the agro-activities.
iv. If the analog value of the soil moisture sensor goes above the threshold, trigger the controller to turn ON the sprinkler using solenoid valve.
v. If the analog value of the float sensor goes below the threshold, activate the controller to turn ON the motor to move the plate at the end of levee so as to remove the excess water.
vi. If the digital value of the IR sensor goes high, turn ON the buzzer.

Fig. 3. Movement of levee on excess water.

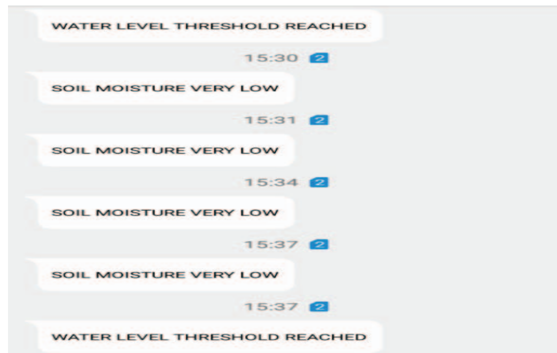

Fig. 4. Messages received in farmer's mobile.

All these information have to be sent via the GSM Module to farmer's mobile and final decision has to be made by famer. Depending upon the DTMF signals, actions are performed by the Arduino without direct manual efforts.

VI. Results

The final prototype has been successfully developed and the entire operation was successfully verified. The prototype was deployed in a field and found to perform the activities as specified. Soil moisture sensor was able to measure the accurate moisture values from the soil and accordingly signals the Arduino to turn on/off the sprinkler with the help of solenoid valve. Float sensor monitors the water level and triggers the Arduino to shear the furrow using a movable plate at the time of excess water by means of rack and pinion arrangement controlled by DC Motor as shown in Fig. 3.

Additionally, prototype was able to interpret external agents and turns on the alarm. Farmer receives the message at the right instant through GSM Module and therefore can call the test mobile attached to the system, which would perform the corresponding activities without much human efforts by means of DTMF Module. Fig. 4 shows the messages received in the Farmer mobile during testing.

The device is capable of monitoring real time agriculture fields with good efficiency. The system was found to be very reliable as it responds least, almost null, to garbage values. Fig. 5 shows the completed arrangement in the small field.

Fig. 5. Prototype arrangement in the real field.

VII. Conclusion

As farmers are struggling to meet the increase in demand for edible products due to lack of labour and money, this prototype will truly be opening a window to the future. It will reduce the burden on farmers by being reliable, efficient, cost effective, accurate and easy to use. This solution aims to improve the quality of life of these people who serve as the backbone of our country as well as our economy. Our society has been looking into the possibility of autonomous agriculture. However, the task of implementing is difficult in the initial stages and requires extensive agricultural techniques. The proposed solution to this problem will enable a farmer with a very small plot of land to taste the success and gradually can extend it to larger fields.

The low cost with one-time investment and ease of maintenance makes this prototype a boon to any farmer. The accurate and effective results significantly lower the effort required by the farmer and will definitely improve the stance of living of the agricultural sector.

There is considerable scope for improvement and addition of features to this device. This prototype can be extended with ease in larger fields to employ other activities like automatic feeding harvester, detection of diseased crops, automatic removal of unwanted weeds etc., so as to develop full time precision agriculture. Also, a real tracking and shooting portal turret with camera can be added for surveillance for the larger fields. The conclusion that can be drawn from this paper is that this prototype for field monitoring and automation in agriculture presents a number of advantages over the existing methods being used in farms around India and will certainly enhance the quality of life of the farmers and also reduce the burden of an already very demanding occupation.

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