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Design and Development of Automated Soil Quality Management System using LabVIEW

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Abstract: *The efficient and profitable production of agricultural products depends on a suitable soil condition. Developing a wireless and Intranet-accessible system to monitor sensor readings and control actuators for determining the optimum soil conditions for agricultural activities to provide information for the farmer with the solutions to maintain the soil conditions is the most challenging work. Remote monitoring and control system (RMS) is easy to utilize and has good reliable facility, providing the efficient monitoring and maintenance of process. In this paper, automated soil quality management system is designed, which is a wireless and Intranet-accessible system using Wi-Fi. Remotely monitored and controlled robot monitors entire field condition in real time, by measuring soil parameters like soil EC (Electrical conductivity), soil pH, soil moisture and atmospheric humidity, even automated regulation of water supply using radio frequency (RF) technology, is provided based on soil moisture level and all this necessary information is provided to farmer at base station on LabVIEW (Laboratory virtual instrument engineering workbench) graphical user interface (GUI) and also through SMS using GSM. Proposed System is implemented using NI (National instruments) LabVIEW and NI myRIO (reconfigurable input output) which has built in Wi-Fi, with web servicing capability. Most useful advantage of the designed system is, it facilitates the re-configuration and re-programming ability remotely, in accordance with the change in environmental condition.*

Keywords: *NI LabVIEW, NI myRIO, Web servicing, Wi-Fi technology, GSM, RF transmitter and receiver.*

1. Introduction

Agriculture is the foundation of Indian economy. Due to the expanding population growth, land deterioration and raising demand for food, a viable and sustainable agricultural system has become a critical issue to achieve. So, in order to overcome this critical problem, the Nations crop production must be increased effectively and efficiently.

Soil quality plays a major role in increasing the crop production. Plants obtain support for their growth from the soil, which manages functions of portioning water and solute flow, maintaining biodiversity and productivity, buffering and purifying and nutrient cycling which reflects the soil nature. Large impact on soil nature is maintenance of soil.

Three essential factors that plants require for their growth and reproduction are light, water and nutrients. However, plants make use of sunlight which is naturally available for their growth and reproduction functions. But the major focus is on water and nutrients which are available by soil to the plants. Sometimes nutrients loss occurs by the soil due to runoff water, erosion and leaching, gaseous losses to the atmosphere and becomes unavailable for plant uptake. The water and nutrients level vary depending upon the type of soil and plants. So, an efficient soil quality management system is needed to be developed.

Precision agriculture (PA) is characterized as the system of applying the perfect measure of input (water, fertilizer or manure, pesticides and so forth) at the right area and at the ideal time to upgrade production and upgrade quality, at the same time safeguarding the environment. PA guarantees snappier reaction times to unfavorable climatic conditions, better quality control of the produce but at a lower work cost.

An advanced tool for PA information gathering is remote monitoring and Control system (RMS), having advantage of cost effectiveness, rapid response, and relatively good spatial resolution. In utilizing RMS for in-field soil property determination has made a tremendous progress. Remote monitoring and control system (RMS) is easy to utilize and has good reliable facility, providing the efficient monitoring and maintenance of process.

The objectives of this project is to help the farmers, by minimizing their risk, advancing production efficiency and quality and minimizing environmental impact on growth of plants. So, by making use of RMS technology, a remotely monitored and controlled robot has been designed, which inspects the field's soil status automatically, by measuring soil moisture, soil pH, soil EC (electrical conductivity) and atmospheric humidity. The designed system also maintains the moisture level in soil automatically, by switching ON or switching OFF the water motor, according to the required soil moisture. Farmer at the base station receives his field status on graphical user interface (GUI) of LabVIEW (Laboratory virtual instrument engineering workbench) and also voice instruction from speakers. SMS (short message service) alert through GSM (global system for mobile communication) is also facilitated in offline mode.

RMS is achieved by the aid of myRIO (reconfigurable input output), which is the fundamental component of designed system, which has built in Wi-Fi (wireless fidelity), FPGA and real time ARM cortex A9 processor. Another main component in designed system is LabVIEW. Developed system is wireless and intranet-accessible system, with the aid of myRIO and LabVIEW with web servicing capability. National Instrument's (NI) LabVIEW is a platform and development environment for a visual programming. The purpose of such programming is automating the usage of processing and measuring equipment. A key benefit of LabVIEW over other development environments is the extensive support for accessing hardware instruments. LabVIEW is the preeminent and skilled programming language for remote monitoring and control system programming.

2. Previous Works

In traditional system, soil sampling method is used, where from the regions of fields the soil samples were taken to laboratory for analysis. This method is not effective because of manual nature of sampling task and is not economically viable. By adopting newly available technologies in the field of agriculture, such problems can be prevented. Tremendous progress had been made in the field of agriculture, by several authors, by making use of different technologies in PA.

A system has been developed, where various types of sensors like temperature, humidity, soil moisture etc, are scattered everywhere in the field to acquire the data, process and analyze the data. For the efficient management of irrigation system a WSAN (wireless sensor and actuator network) is used, which provides proper farmland supervising, human intervention is less, lower cost and also provides accurate and instant decision [1]. Irrigation controller system, which is automatic and is efficient during both heavy rainfall and dry conditions, was developed using WSN (wireless sensor networks), 8052 microcontroller is used to process the data, UART for serial port communication and GSM is used for mobile communication [2], [3], [6].Survey on different technologies of WSN and standards applied to the field of agriculture and also on existing issues in physical layer of zigbee is done and developed WSN using Zigbee, for monitoring several environmental parameters that affect the growth of plant and provide irrigation facility which is automated [4]. A remote monitoring system using wireless protocols is developed for measuring soil temperature, moisture and relative humidity using XBee module, FPGA element and UART [7]. At different positions in field, wireless moisture sensors are fixed to check the moisture level of field using Zigbee WSN [8], [9]. Wireless sub soil sensing system of low cost and power to measure soil moisture and to manage soil moisture in PA was developed and a range of sensors hosted by RFID (radio frequency identification) sub-soil system, communicates information to the farming vehicles wirelessly and the farmer can take required control actions [10].

In the overview of the survey, investigation is done on the concepts of several authors in the field of agriculture. Even though these concepts are advantageous and had made a tremendous progress in the field of farming, using various communication techniques, they were not affordable economically and size of hardware designing is more. Hence, to obtain the entire farmland situation, sensors were fixed everywhere in field, which increases systems, hardware size and expenditure. This drawback is prevented by the proposed system.

In the proposed system, since the remotely monitored and controlled robot is designed, the sensors are fixed to the robot and robot is able to move all around the field to get the exact field condition without scattering many sensors all around the field. Since NI myRIO has in built FPGA, real time processor and Wi-Fi which facilitates wireless communication and web servicing, which is of small in size and fixed to robot, this effectively reduces the size of the hardware and expenditure.

3. Proposed Work

3.1 Hardware Design

The approach for designing a high level automated soil quality management system is shown in Fig. 1. The system is mainly incorporated with electronic and electrical peripherals. Robot with NI myRIO device is the fundamental component which performs operations of monitoring, controlling and management of the entire designed system. NI myRIO is internally embedded with 667 MHz dual core ARM cortex-A9 programmable real time processor, a customizable Xilinx field programmable gate array (FPGA), LINUX operating system and Wi-Fi [12]. This device been interfaced with various sensors like soil moisture sensor (gives information regarding water content in soil), soil pH (gives information regarding acidity or basicity of soil), soil electrical conductivity sensor (gives information regarding nutrients level in soil) and atmospheric humidity sensor(gives information regarding water present in air), for determining real time physical parameters of soil, such as, soil moisture, soil pH, soil EC and atmospheric humidity respectively.

NI myRIO is even interfaced to servo motor, to which arm is fixed. NI myRIO is also interfaced with motor driver; to drive the two dc motors connected to driver, for the movement of the wheels hence the movement of robot. Finally, NI myRIO is interfaced to RF transmitter, to enable wireless RF communication with water supply section, to which RF receiver is fixed. Power supply to NI myRIO is obtained from 12V battery and it also supply power to the motor driver. Sensors, servo motor and RF transmitter, gets 5V of supply from myRIO.

The water supply section is incorporated with RF receiver, relay and water pump, in order to turn ON the pump. When RF receiver receives a digital signal from RF transmitter, it triggers the relay and relay drives the water pump. The power supply units, supplies sufficient power to RF receiver, relay and pump.

Laptop/PC with LabVIEW user interface, GSM and Speakers are the peripherals incorporated at base station. The wireless communication between base station and robot at the farmland is facilitated via web service, using web publishing tool of NI LabVIEW.

In designed automated soil quality management system, remotely monitored and controlled robot with NI myRIO device is designed, whose performance is vital. Predefined path had been assigned to the robot, for movement all over the farmland and to validate the status of farmland to the farmer. Since, soil physical parameters like soil moisture, soil pH and soil electrical conductivity are to be measured to the depth of soil, therefore they are been fixed to the arm of the servo motor. So, in accordance with the given angle (PWM (pulse width modulation) pulses from myRIO fed to servo motor), the arm dips these three sensors up to some specified time deep in to the soil, for determining the real time values and lifts the sensors up, after measuring and this process is done all over the field.

When robot encounters that soil moisture is lower than the threshold range, using RF transmitter it sends a digital signal to RF receiver wirelessly. On receiving the digital signal, RF receiver triggers the relay connected to it, in turn relay drives the water pump, to pump the water to the farm. Robot continuously measures the soil moisture, until it reaches the threshold level, then sends signal to turn off water pump to the RF receiver via RF transmitter. In this way the system regulates the supply of water to the farmland.

All these measured real time data are conveyed to the farmer at base station via web service is facilitated by web publishing tool of LabVIEW. By entering an appropriate URL (uniform resource locator) in the web browser, the farmer access control of LabVIEW front panel on web page, which provides information regarding the status of his farmland, at what time (date and time) the field is inspected and also voice instructions of status from speakers. Simultaneously he also receives a SMS regarding the farmland status, using GSM module. With his interest, he can manually control robot and turning ON and OFF of water pump. Having information about the status of his field, farmer can take applicable actions to improve the status of the farmland. Most useful advantage of the designed system is, it facilitates the re-configuration and re-programming ability remotely, in accordance with the change in environmental condition.

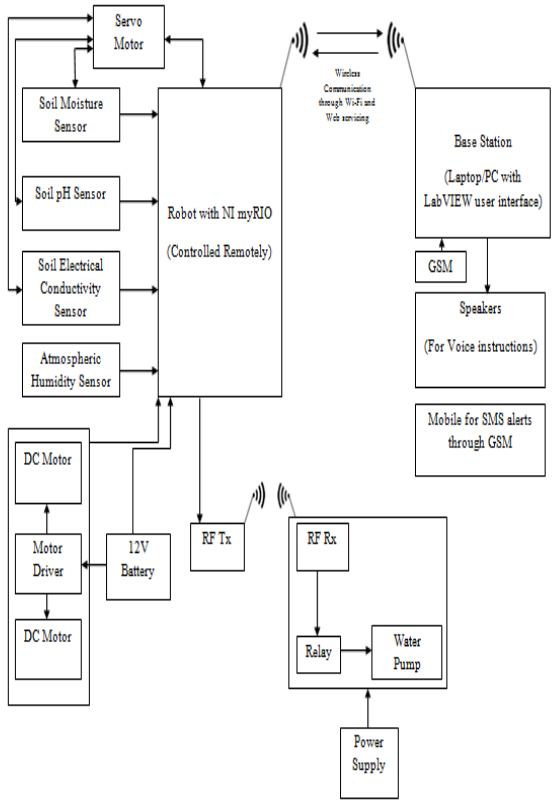

Figure.1 *Block diagram of automated soil quality management system*

3.2 Software Design

Designed front panel (GUI) in LabVIEW for automated soil quality management system is as in Fig. 2. LabVIEW programs are called virtual instruments (VIs).Interactive input and output terminals are controls and indicators respectively in the front panel of LabVIEW. User interface of VI is front panel. By entering an appropriate URL in the web browser, farmer gets access to the front panel in LabVIEW, which is in Fig. 2. Status of the entire field is obtained through this page.

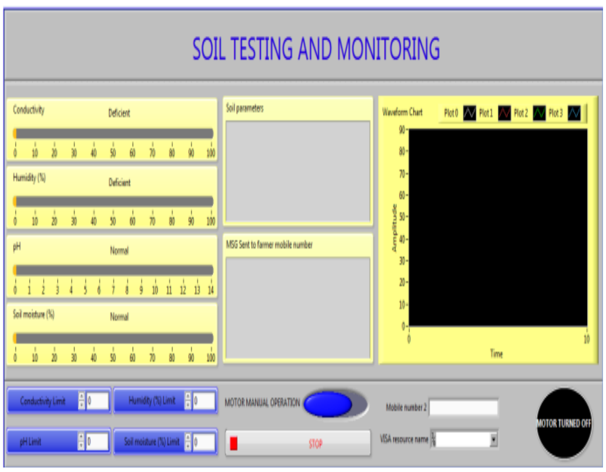

Figure.2. *Designed front panel (GUI) in LabVIEW of proposed work*

Information regarding soil physical parameters is displayed, in accordance to the determined values; appropriate text is also displayed above the measured value, as in the left side of the fig. 2. At the bottom left corner of fig. 2, conductivity limit, humidity (%) limit, pH limit and soil moisture (%) limit, represents the minimum value of these four parameters that soil should have for good status of farmland. The soil parameter block in the top middle of fig. 2, gives the time and date of field inspected and status of soil parameters CEC (cation exchange capacity), porosity and salinity related to soil EC. Below that, message sent to farmer mobile number block indicates the message sent to farmer. At bottom right corner mobile number, VISA resource name and motor turned off indicates the mobile number to which message is to be sent, to which port GSM is connected and status of water pump (either ON or OFF) respectively. Waveform graph to the top right corner indicates the measured soil parameters graphically. A Boolean switch to the bottom is the manual control of water pump provided to farmer.

Usually programming in LabVIEW and myRIO facilitates three styles of programming, real time (RT) programming, FPGA programming, where these two codes run in processor of myRIO and host programming, which runs in laptop/PC. When the code is deployed in RT processor of myRIO, the acquisition of samples is less when compared to dumping a code in FPGA of myRIO. FPGA programming provides increased accuracy when compared to RT programming. RT programming is mainly for manipulation and calculations. My RIO is integrated with LINUX operating system, some codes will not support coding in LINUX (ex GSM), so host programming is used.

In the designed code we make use of all three types of coding. In FPGA obtained raw data is converted to voltage using the appropriate conversion factor. In RT the voltage values are manipulated, to convert the voltage to required units by some mathematical calculations. In host, which codes are not supported by LINUX, are coded. The network shared variables are shared between these three programming styles.

4. RESULTS

Some threshold ranges are assigned for each of the measured soil parameter, within this fixed threshold range the soil status will be well balanced, to obtain better crop productivity. When the measured values goes out of range (either less or more than the nominal range), farmer needs to take the applicable actions to maintain good status of soil. Fixed threshold ranges for soil parameters in proposed system and required actions taken by farmer are shown in table. 1. Fig. 3 shows the designed prototype of proposed work.

a. Robot with myRIO and sensors
b. Prototype under test

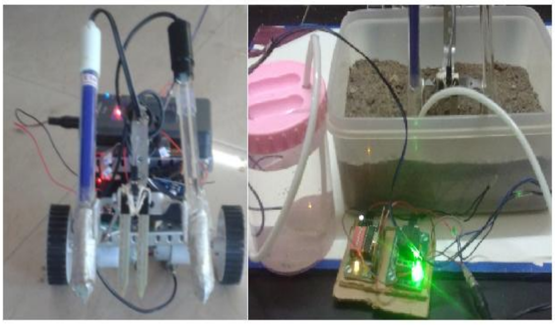

Figure.3. *Designed prototype of proposed work*

When robot inspects the soil condition and sends the information regarding soil status remotely to farmer, the results are displayed on the front panel (graphical user interface) of LabVIEW as shown in fig.4. This front panel (GUI) is published on the web page with the aid of web publishing tool of LabVIEW. By entering the appropriate URL in the browser, farmer can access GUI on web page, which displays the condition of his field, by providing necessary information regarding soil status and he can access manual control over robot and water motor through this page. This web page showing results of soil status is shown in fig. 5. This page gives information regarding soil moisture, soil pH, soil EC and atmospheric humidity.

Table.1 *Threshold ranges of soil physical parameter*

Soil physical parameters	**Normal range and action taken**	**Deficiency range and action taken**	**Excess range and action taken**
Soil moisture (0-100) (%)	50-80 (Balanced water content, motor turns OFF automatically)	<50 (Water motor turns ON automatically)	>80 (Water motor turns OFF automatically)
Soil pH (0-14	5-8 (Well balanced nutrients, no action needed)	<5 (Farmer manually adds required micronutrients)	>8 (Farmer manually adds minor nutrient elements)
Soil EC (0-100) (μs/cm)	30-80 (Well balanced organic matter, pores and salts, no action needed)	<30 (Farmer manually adds required fertilizers)	>80 (Farmer manually controls the level of fertilizers)
Atmospheric humidity (0-100) (%)	60-80 (Well balanced surrounding temperature, no action needed)	<60 (Farmer takes action to increase soil temperature)	>80 (Farmer takes action to decrease soil temperature)
Text displayed above obtained reading	Normal	Deficient	Excess
Soil parameter related to soil EC	Cation exchange capacity is normal, Salinity is normal, Porosity is normal	Cation exchange capacity is abnormal, Salinity is abnormal, Porosity is abnormal	Cation exchange capacity is abnormal, Salinity is abnormal, Porosity is abnormal

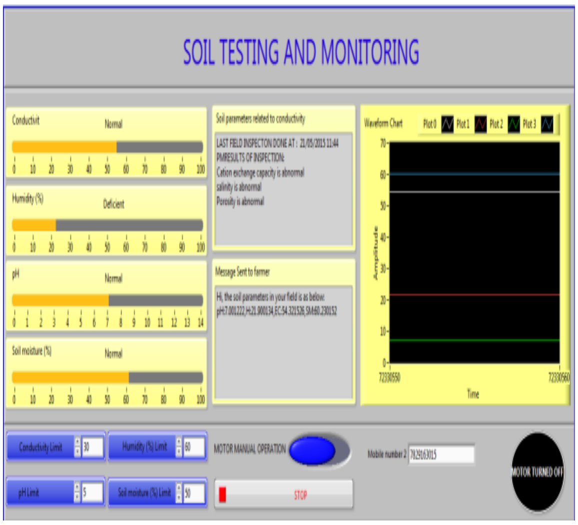

Figure.4. *Results of soil status displayed on LabVIEW front panel (GUI)*

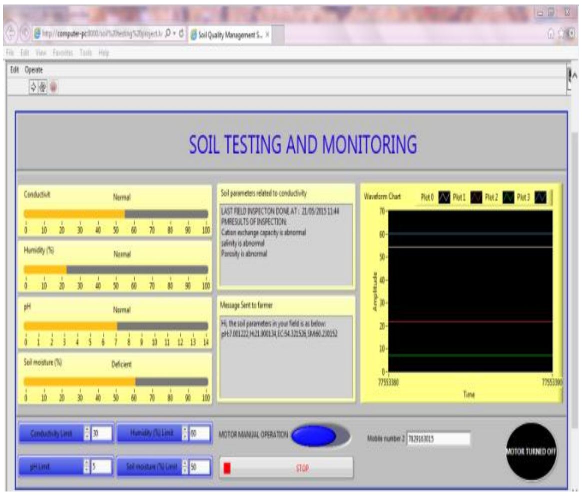

Figure.5. *LabVIEW front panel (VI) published on web page*

maintenance of process. Proposed work is implemented using NI LabVIEW and NI myRIO with web servicing capability for developing a wireless and Intranet-accessible system. LabVIEW is the preeminent and skilled programming language for remote monitoring and control system programming. Designed system facilitates re-configuring and re-programming remotely, depending on environmental conditions.

The corresponding SMS alert regarding the measured soil parameters will be obtained on farmers mobile through GSM. The SMS obtained on farmers mobile is shown in fig. 6.

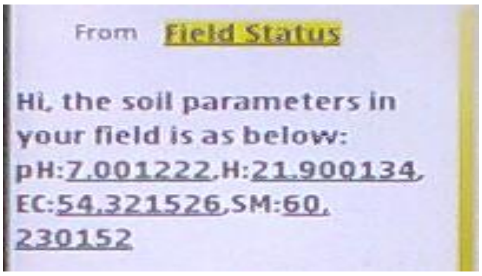

Figure.6. *SMS alert in farmers mobile*

5. Conclusion

The developed system is automated and manages soil status effectively and efficiently and also reduces risk to farmers. Remotely monitored and controlled robot monitors soil status, by measuring soil EC, Soil pH, soil moisture (automated water supply regulation is provided depending on soil moisture level, using RF module) and atmospheric humidity and thus providing necessary information to the farmers through web servicing and also SMS is sent to farmers mobile. The proposed system is mainly developed for the betterment of farmers and Nation. Remote monitoring and control system (RMS) is easy to utilize and has good reliable facility, providing the efficient monitoring and

6. Future Enhancement

The proposed system is implemented using NI LabVIEW and NI myRIO with web service capability for developing a wireless and Intranet-accessible system which helps to monitor his field condition remotely. This proposed system can be enhanced with Internet-accessible facility. So that farmer can maintain his field from any part of the world. The proposed system can be enhanced furthermore by adding various sensors like Atmospheric pressure sensor, leaf wetness sensor, soil temperature sensor and so forth.

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