

A Novel Approach towards the Design of an Efficient Embedded System for optimizing the usage of Fertilizers

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Abstract— Agriculture is a chief source of livelihood for majority of Indians and has a great impact on the economy of the country. Use of fertilizers like urea, for increasing the yield of agricultural production is prevalent amongst the farmers. Several studies show that farmers have little control over usage of optimum level of fertilizers for optimal crop yield. Also, usage of fertilizers more than the requisite level produces crops with increased fertilizer content which upon consumption leads to several harmful diseases. Thus most of the edible crops cultivated are under high-fertilizer content setting. In this paper we present a system which shows how an efficient embedded fertilizer monitoring system can ensure millions of farmers to have information about the precise amount of fertilizer to be used for a particular soil type. The system is built with a raspberry pi as a host processor that is used to control and manipulate the sensors and a web database server that is used to validate and store data.

Keywords—Raspberry pi, fertilizer consumption, electrical conductivity, 5TE sensors, SDI-12, database, apache web server.

I. INTRODUCTION

Agriculture forms the backbone of our country and has a significant history. It contributes approximately 16.6% of the total GDP of our country. The overall socioeconomic fabric of India is hugely dependent on agriculture. Agricultural produce is cultivated with the assistance of fertilizers. The usage of such synthetic fertilizers has been increased from 0.7million tonnes (in 1950-51) to 23million tonnes in 2010-11[1]. The usage of fertilizers leads to a boost in agricultural productivity. The fertility of the soil is increased by their usage. However, it has been observed that the usage of fertilizers in an optimum quantity would only result in excellent crop yield, while the usage of fertilizers in a quantity which is larger than necessary would damage the soil and would also result in crop diseases. [2] Offers a number of scientifically documented examples which reveal that continuous usage of excess amount of fertilizers resulted in a decrease in crop yield due to loss of organic content and nitrogen. The human impacts due to pollution caused by fertilizers were also reported. Root burns, diminished plant health and various diseases were also

noted in the crops which were exposed to excess fertilizers. The most important reason behind such usage of high fertilizers is that the farmers are unaware of the exact amount of fertilizer needed by the crops at the exact time and those amounts differ for every variety of soil and water that has been used for irrigation. Though those data are available in the Internet in a myriad ways, most of our Indian farmers are not educated enough to operate a computer. It thus becomes impossible for them to access those data. As a remedy to the above discussed problem, we are introducing a cutting edge embedded system based technology which is economic, reliable, and responsive for the current requirement and helps the farmers to monitor the amount of fertilizers being continuously used for optimum crop yield and hence provides the required information in a user-friendly manner. This system would help the farmers update themselves with the necessary information for developing a healthy crop structure. This system is user-friendly as it measures only the Electrical Conductivity and other vital parameters of the soil without disturbing the crop structure. The Electrical Conductivity (EC) is the measure of the amount of electrical current that can move through water. When a salt is dissolved in water, it breaks into positively charged cations and negatively charged anions. Since these anions and cations have an electrical charge they contribute to the flow of current through water, which determines the electrical conductivity. So, greater the amount of salt dissolved in water, greater would be the electrical conductivity. Since the fertilizers and other nutrients that are absorbed by plants are nothing but salts, the measure of electrical conductivity of the soil would give us a measure of the amount of nutrients that are absorbed or yet to be absorbed.

II. SYSTEM DESCRIPTION

Fig.1. shows the general block diagram of the proposed system. The vital parameters like EC, temperature and moisture level are measured by the sensor module and are sent to the raspberry pi. Once these data are received by the raspberry pi, a query is posted to the database via the internet with the given parameters and the database will respond with the corresponding status. The received status

is stored by the raspberry pi and displayed via the user interface as and when required by the farmer.

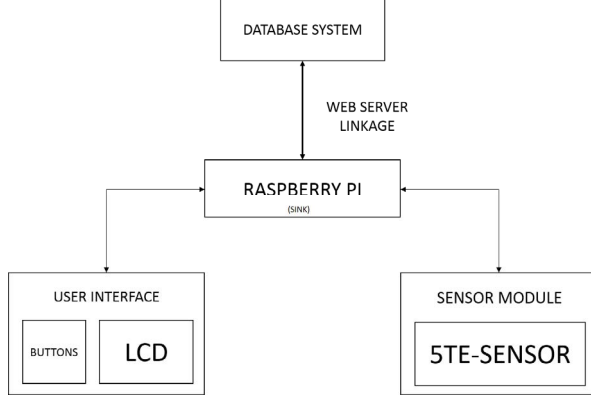


Fig. 1. General block diagram of the system

III. INTERFACING

A. Raspberry Pi

The raspberry pi forms the heart of the system. It is a credit card sized single board computer. The cost of this board made it a huge sensation in the embedded system domain. The main reason behind choosing raspberry pi is that it's very cheap and user friendly since it has an option to connect to the internet using an Ethernet cable or a dongle, and the database server can be accessed easily. Also coding of the program can be done easily. The SoC of Raspberry Pi is Broadcom BCM2835. This contains an ARM 1176JZFS, running at 700MHZ and also has a video core 4 GPU. It has 26 dedicated GPIO pins including the UART, an I2C bus, a SPI bus. The maximum number of GPIOs can be expanded using the I2C or SPI bus. It also has a 512 MB SDRAM[3][4]. The Raspberry Pi works on RASPBIAN OS. Fig.2 shows a raspberry pi-model B.

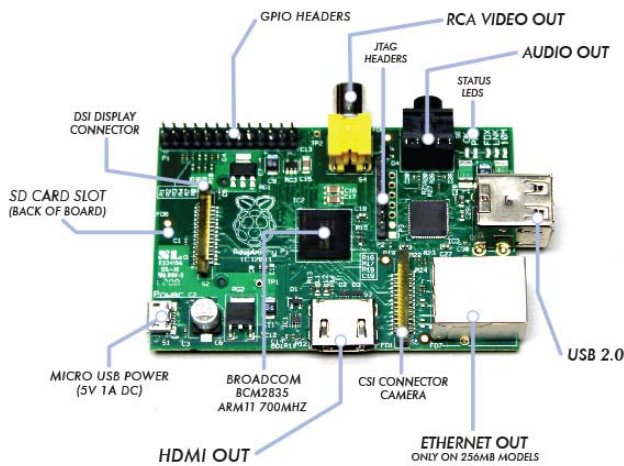


Fig. 2. Raspberry Pi-model B

B. Sensors Used

The sensor that has been used in this system is the 5TE model, produced by Decagon Devices, Inc. This sensor measures the volumetric water content, soil temperature and Electrical Conductivity (EC) values. These sensor works at 70MHZ frequency which minimizes salinity and textual effects. The sensor's small size makes it easy to install it perfectly in field conditions. The temperature is measured by using an on board thermistor. The polyurethane coating on the 5TE circuit board protects the components from water damage and gives the sensor a longer life span [5]. Fig.3 gives us the information regarding the components present in the sensor.

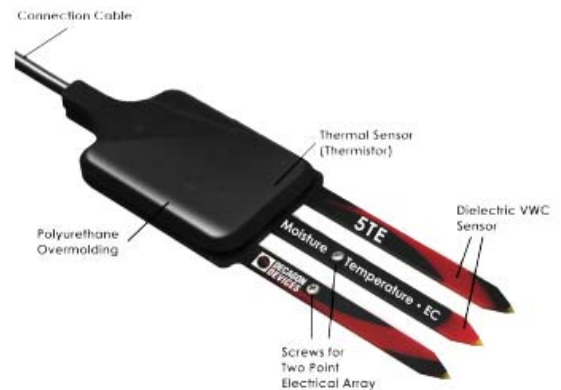


Fig. 3. 5TE components

1) Relationship Between Electrical Conductivity and Crop Yield: As we all know, soil serves as the primary growth medium for crops. It is evident that the maps of the soil's physical properties and the yield maps show correlation. [6] Suggests that soil electrical conductivity can be used as a measure for crop productivity. The soil EC and yield maps shown in fig.4 serve as an example of fields that exhibit similar spatial patterns.

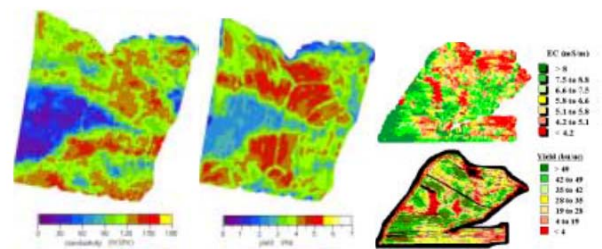


Fig. 4. Examples of EC level and yield maps; durum yield in Australia (left) and soybean yield in Alabama (right).

Also the relationship between soil EC and crop yield is not linear. [7] Portrays this information. Fig.5 shows the non-linear relationship between soil EC and crop yield.

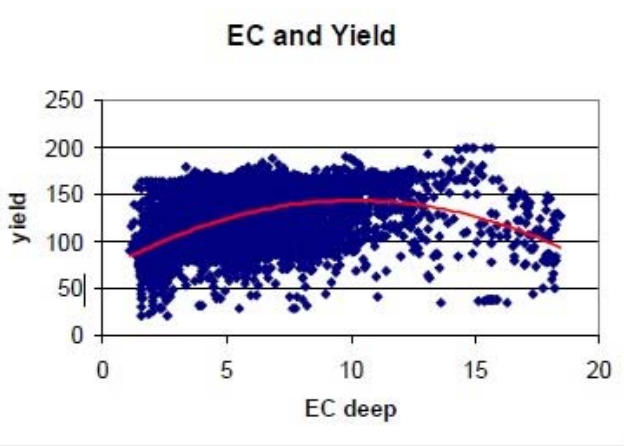


Fig. 5. Non liner relationship between EC and corn yield In Michigan

a) *Factors affecting Electrical conductivity:* Apart from the salt dissolving capacity in water, there are many other vital factors that determine the electrical conductivity. The conduction of electricity in soils takes place through the moisture filled pores that occur between the individual particles of the soil. Therefore the EC is determined by various soil properties that are discussed below [8].

- Pore conductivity- Soils with water-filled pore spaces that are connected directly with neighboring pore spaces tend to conduct more electricity. Soils with high clay content have numerous, small water-filled pores that are quite continuous and usually conduct electricity better.
- Water content - Dry soils are much lower in conductivity than moist soils.
- Salinity level – An increasing concentration of electrolytes (salts) in soil water will dramatically increase soil EC
- Temperature – soil temperature is one important property that determines the EC. A 2% of change in EC is noted for every degree rise in temperature.

2) *Electrical Conductivity-Measurement:* The EC is measured by applying the alternating current to two electrodes and measuring the resistance between them. Conductivity is then calculated as the product of inverse of the resistance and cell- constant, where cell- constant is the ratio of distance between the electrodes to their area. The 5TE sensor basically measure the bulk EC of the medium with the measurement is said to have the accuracy within the range of $\pm 10\%$ for the EC values ranging between 0 to 7 ds/m.as decagon device suggests this range is adequate for most field, greenhouse and nursery applications[5].

a) *Converting Bulk EC to Pore EC:* As said earlier, this device measures the bulk EC value. But a good knowledge of the pore EC value (σ_p) gives us information about the salt concentration in the soil. [9] gives us the advantage of assuming a linear relationship between the soil bulk dielectric permittivity(ϵ_p) and bulk EC(σ_b),so that σ_b can be converted accurately to σ_p , provided ϵ_p is known. The 5TE measures ϵ_p and σ_b nearly simultaneously in the same soil

volume. The pore EC(σ_p) is calculated by using the following formula, suggested by [8].

$$\sigma_p = \frac{\epsilon_p \sigma_b}{\epsilon_b - \epsilon_{\sigma_b=0}} \quad (1)$$

Where $\epsilon_{\sigma_b=0}$ is the real portion of the dielectric permittivity of the soil when bulk electrical conductivity is 0 (unitless); ϵ_p is the real portion of the dielectric permittivity of the bulk soil (unitless); ϵ_p can be calculated from the soil temperature using the formula

$$\epsilon_p = 80.3 - 0.37 * (T_{soil} - 20) \quad (2)$$

Where T_{soil} is the soil temperature; Decagon Devices recommends using $\epsilon_{ab}=6$ for more accurate calculations of σ_p .

C. SDI-12 Communication Protocol

The 5TE sensor communicates to the data recorders (data recorders address the raspberry pi in this case) using 2 different methods-TTL and SDI-12. We are utilizing the SDI-12 protocol in our system. SDI-12 is a standard for interfacing data recorders with microprocessor based sensors like 5TE. SDI-12 stands for serial/data interface at 1200 baud. SDI-12 is intended for applications which operate at minimal current drain, low system cost and using a single data recorder with multiple sensors on a single cable [10]. The advantages of using SDI-12 communication are:

- Unique and complex self-calibration algorithms can be done in microprocessor based sensors
- Sensors can be interchanged without reprogramming the data recorder with calibration or other information.
- Power supply to the sensors is done through the interface
- The Hybrid circuit and surface mount technologies help us to include microprocessors and other needed circuits in small sensor packages.

The acquisition of data from the sensors happen as described below [10]

- The sensors are woken up by a break on the SDI-12 bus by the data recorder(raspberry pi)
- The raspberry pi transmits a command to a specific, addressed sensor, instructing it to make a measurement
- The addressed sensor responds within 15.0 milliseconds returning the maximum time until the measurement data will be ready and the number of data values it will return.
- If the measurement is immediately available, the recorder transmits a command to the sensor instructing it to return the measurement(s). If the measurement is not ready, the data recorder waits for the sensor to send a request to the recorder, which indicates that the data is ready. The recorder

then transmits a command to get the data. The sensor responds, returning one or more measurements.

The raspberry pi cannot be connected to the SDI-12 protocol directly [11]. So we are using an RS232 to SDI-12 converter so that the raspberry pi can be connected to the sensor via the UART (fig.6.). Fig.7 shows us the timing diagram of the SDI-12 sensor

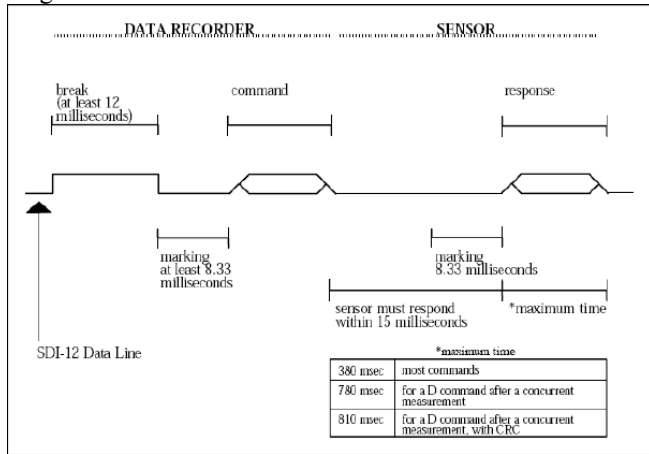


Fig. 6. Timing diagram for SDI-12 interfacing

1) SDI-12 Format Description for Sensor Interfacing: The data string output by the sensor should be in a format similar to the one below:

56 432 645<0D>zG<0D><0A>

Table1.gives us a detailed description of the commands:

TABLE I. DESCRIPTION OF COMMANDS

command	description
56	Sample Raw apparent dielectric(Raw apparent dielectric=50*dielectric)
432	Electrical conductivity in mS/cm multiplied by 100
645	Temperature. This number is 10*T + 400, where T is the degrees Celsius
<0D>	This carriage return character signals the end of the measurement string and start of the meta data string.
z	Sensor Type. This character is used to indicate the sensor type. Z is used for 5TE sensors.
G	Checksum. To Check validity of data
<0D><0A>	The carriage return and line feed are used to signal the end of the meta data section and the end of the transmission.

2) SDI-12 Typical Outputs: Typical output while the sensor is suspended in air 20°C will be approximately: 50 0 600, which translates into a dielectric = 1, EC = 0, T = 20°C.

If the sensor is fully suspended in 20C tap water, the outputs will be approximately: 4000 50 600, which translates into dielectric = 80, EC = 0.5 dS/m, T = 20°C. Note that the raw dielectric output in water can range from 3400 to 4094, and that the EC of tap water is highly variable depending on the source.

D. Connections-Pin Diagrams

The sensor module and the user interface module are connected as shown in the fig.6. Since the GPIO pins have to be used effectively, we are using the 4 bit format for the 16x2 LCD. The other 2 pins that has been connected, is used to send the data. The RW bit of the LCD module is grounded so that the LCD is in write mode. A button has been connected to another GPIO. The sensor is connected via the UART (i.e. pins 8 and 10 of Raspberry pi).

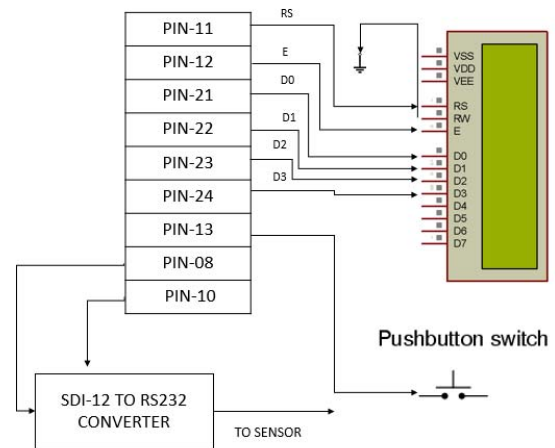


Fig. 7. Pin diagram of the system

E. Database

The pre-defined data, with which the sensor values are validated, are stored in the database. The database has to be accessed by many raspberry pi's (i.e. more than one system). So, instead of having a local database in each raspberry pi, we are using a centralized database server. This would help us to access the database from more than one system. Also the values that are stored in the database vary for each and every region, depending upon the nature of the soil and water. So, having a database based system would help us to create separate databases for every region. This implies a change in the database instead of a change in the system alone. This makes our system financially feasible and efficient. The data are basically stored in the database in the form of a table, with rows and columns. The data are nothing but the benchmark EC, temperature and moisture values. The data acquired from the raspberry pi are queried

to the database server. The database server compares those values with the table and would conclude what the current status of the soil is, i.e. whether the fertilizer amount is under control or do we need more of the same. This conclusion is sent back to the raspberry pi, which in turn displays it via the user interface module. This database can be designed using any methods like sql, mysql, php, etc.

1) *Installing Vital Software in Raspberry Pi:* For setting up of the raspberry pi to the end user, the system has to be installed with the python packages, which assists in computing and processing of the parameters measured using the sensors.

2) *Webserver:* Raspberry pi is capable of installing light-weight and efficient webservers that help in bridging the system with the remote servers which ensures availability of data and the responsiveness of the system. The remote database server implemented with the help of cloud storage will provide adequate space to store the data and would not strain the remote raspberry pi systems for storage purposes. The system that we are going to implement is using Apache webserver, which is light-weight and efficient for an embedded system. The Apache webserver is capable of serving HTML and other dynamic content within the local network [12]. To do the same in Internet level, we need to run a server side script such as Python. Python will allow us to connect to our database, thereby reading and writing from it. Web Server Gateway Interface (WSGI) is another additional standard that has to be installed. This allows us to access the centralized database server from the raspberry pi [13]. Fig.8 shows us the block diagram representing it.

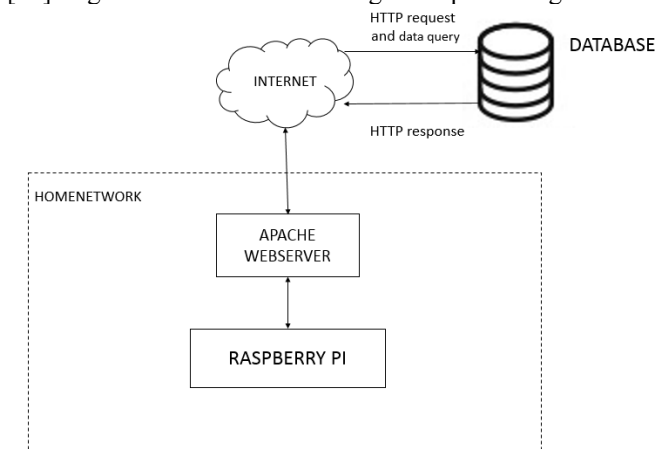


Fig. 8. Apache webserver-block diagram

IV. CONCLUSION

The raspberry pi based fertilizer monitoring system proves to be a robust, real time feedback control system which monitors and controls all essential components of fertilizer content analysis efficiently. The present system is a model to modernize agricultural practices on a large scale with nominal expenditure. This system provides great impetus into optimizing the fertilizer levels employed for crop cultivation. The webserver database management system ensures an organized method for essential data

storage. Usage of Raspberry pi for processing and manipulation of data from the webserver linkage ensures the credibility of stored information. This system improves overall quality of the harvest, guaranteeing safety for the consumers.

V. FUTURE WORK

In future, the system can be expanded to generate monthly reports and to give an enhanced option for the farmer, vis-à-vis which crop is most feasible for the current climatic and soil conditions. To append more intelligence, we can increase the number of sensors and which monitor the environmental as well as climatic factors and make the system an improved one. Having an automatic control system embedded to the existing system would enable us to properly apply the fertilizers to the soil automatically according to the parameters, thereby decreasing the burden of farmers. The fertilizers are applied by a method called fertigation and the control system mentioned above is used to control the fertigation process. The control system can be designed by either an open loop method or closed loop method depending upon our requirement.

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