Design of a Cost Effective Soil Monitoring System to Support Agricultural Activities for Smallholder

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Abstract

The moisture, temperature and electrical conductivity of soil are the important properties for agriculture. It is necessary to monitor such data in order to support the agricultural activities, especially improve the yield and reduce the irrigation water. However, the currently commercialized monitoring systems are too expensive for the smallholder who has less than two hectares of farmland. The objective of this study is to develop a cost effective system for monitoring the soil data, which consists of a monitoring device and a web-based application. The monitoring device measures the soil information every one hour and then transmits such data to the cloud for storing and visualizing. The system has been testing in the experiment field to evaluate the system’s stability.

Keywords: Soil monitoring system; internet of thing.

1. Introduction

Soil information, such as temperature, moisture, electrical conductivity (EC), is an important property for agriculture, indicates the health of the soil. Such data are necessary for precision farming, for example, it can be used for decision-making in smart irrigation, that increases the production yield while saving water. It also contributes to an optimal fertilization decision support system [1]. Although much commercialized monitoring systems are available, they are still expensive for smallholder. Many researchers have been developing the cost-effective monitoring system by integrating new Internet of Thing technologies. For example, a soil moisture monitoring system based on wireless sensor network was introduced in [2], which consists of a coordinator and end nodes communicating together via LoRa Radio (RFM9x) and data has been sent to the ThingSpeak (https://thingspeak.com) – a Cloud Internet of Thing platform – by the coordinator through WiFi connection. The system has shown the effective solution for smart-agriculture in United State with the cost about $300 (for one coordinator and one end node). In [3], a GPRS-based monitoring system for soil water content and other parameters was developed by using Arduino (open-hardware platform) with the low-cost at about $250. In general, the simple method to decrease the system cost is to use the open source hardware and software platform [4-5].

Most of the farmers in Vietnam are smallholders who have under two hectares of farmland and the agricultural practices are traditional farming which is based on individual’s experience. This can lead to waste of water and fertilizer. It is necessary to transform from the traditional farming to precision farming. Precision farming needs sensors to measure environmental information in order to manage the crop conditions and increase the productivity. Soil information monitoring is one of the technologies that farmers can use to schedule irrigation, which increases the yield while saving water. However, the current commercialized soil monitoring systems are still expensive for a smallholder to invest. Thus, this study aims to develop a communication system to monitor the soil parameters for supporting agricultural activities in order to empower smallholders. Moreover, the platform is
simple and inexpensive by using open-source hardware and software, which can offer options for collecting, viewing and sharing data via a cellular communication network.

2. Cost Effective Soil Monitoring System

2.1 System Overview

The proposed system’s overview is shown in Figure 1. It can be divided into two main components: monitoring device and data server. The monitoring device is responsible for collecting soil information and then transmitting data to the data server through GPRS connection. It integrates a programmable microcontroller with a built-in cellular communication module, solar module and rechargeable battery, allowing it to transmit data to the internet and operate in a long-term period. The main ability of the monitoring device is that it can interface with the commercialized soil sensor via the SDI-12 protocol, but it can be modified to suit with other sensors. The data server is built for collecting and storing data from multiple monitoring devices and providing data visualization for farmers and researchers.

![Figure 1. Soil monitoring system overview](image)

2.2 Monitoring Device

The architecture of monitoring device comprises of 4 modules including a processor, a sensor module, communication module and power module (refer to Figure 2). All components are housed in a weatherproof enclosure for outside deployment.

We utilize an Arduino Pro Mini board as the processor module. It is based on an Arduino platform which is the best-known as an open-source electronic hardware and software platform. The board provides a 8 bit microcontroller, which combines 32KB ISP flash memory with read-while-write capabilities, 1KB EEPROM, 2KB SRAM, 23 general purpose I/O lines, 32 general purpose working registers, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, 6-channel 10-bit A/D converter. The board can be powered from 5 to 12 DC supply voltage so that it is able to power the board with 4 or 5 AA batteries. The microcontroller is programmed using open-source Arduino Integrated Development Environment – Arduino IDE.

For communication module, we use a GSM module (SIMCOM SIM800L module) to transfer soil data to the internet via GPRS connection. This module connects to the
processor via UART protocol using AT command. The module only operates at 3.7V – 4.2V. Thus, the DC-DC voltage converter (MP1584 module) is used to convert power supply voltage (from batteries) to 4.2V in order to power the GSM component. The module needs SIM card and cellular data plan to enable cellular communication.

The device can connect to the commercialized soil sensor via the SDI-12 protocol. In this study, we choose a 5TE soil sensor (Decagon Device Inc., Pullman, WA, USA) because it can measure multiple soil parameters with the high quality of data. The accuracy of measurement data is important for the research analytic to integrate to the agricultural supporting system.

The 5TE sensor can measure dielectric permittivity, bulk electrical conductivity and temperature [5]. For mineral soil calibration option, the dielectric permittivity value ($\varepsilon_a$) can be converted to volumetric water content (VWC) of soil by using the Topp equation [6]:

$$VWC = 4.3 \times 10^{-6} \varepsilon_a^2 - 5.5 \times 10^{-4} \varepsilon_a^2 + 2.92 \times 10^{-4} \varepsilon_a - 5.3 \times 10^{-2}$$

### 2.3 Data Server

The data server is built as a web-based application, which can collect and store data from monitoring devices and visualize data as graphs. Storing data for the long-term period is very important for analytic to understand difference crop condition. The application is developed using Python Flask platform (http://flask.pocoo.org/) which a micro web framework is written in Python. The application is deployed on Heroku Cloud platform (https://heroku.com) – a cloud platform as a service (PaaS) supporting several programming languages such as NodeJS, PHP, Java, Python, etc. Heroku provides an element called Add-ons that allow user fastly to integrate third-party services such as data storage, metrics and analytics, etc.

To transfer data from a monitoring device to the data server, each device needs a unique secret key in order to send data to the server using HTTP GET protocol. Table 1 shows the HTTP protocol structure for transmitting data from a monitoring device (with the secret_key=123456789abc) to the data server (with the host=cosin.herokuapp.com). The sensor data are formatted as follow val1=<value1>&val2=<value2>&val3=<value3>. In the proposed system the 5TE sensor is used so that the value1=dielectric, value2=bulk electrical conductivity and value3=temperature.

| Table 1. HTTP GET structure for transmitting data |
3. Experimentation and Result

The Figure 3 shows the monitoring device that is set up in the experiment field. In this experiment, we set one hour as the sampling time so that the device takes a sensor reading and transmits data to the internet every one hour. Although the device has been designed to work in the save-power mode, the power consumption needs to be considered because of the use of GPRS connection. To solve the power consumption problem, the device is powered by 5 AA rechargeable batteries combined with the 6W solar power module for long-term measurement in the experiment field. The total cost of building a monitoring device is $306.5 (refer table. 2) so it is possible for a farmer to invest.

To access the data, users can access the specific device website (http://cosin.herokuapp.com/chtien18/showgraph). The data are visualized as graphs and available to download for analytic purpose. In this paper, we download data from the device’s web page and use Microsoft Excel to calculate the VWC of soil based on Topp equation. The Figure 4 shows an example graphs for the 24 hours sensor measurement. The data is transmitted every 60 minutes without data loss.

<table>
<thead>
<tr>
<th>HTTP GET structure</th>
<th>HTTP GET</th>
</tr>
</thead>
<tbody>
<tr>
<td>https://&lt;host&gt;/&lt;secret_key&gt;/write/val1=&lt;value1&gt;&amp;val2=&lt;value2&gt;&amp;val3=&lt;value3&gt;</td>
<td></td>
</tr>
</tbody>
</table>

| Example | https://cosin.herokuapp.com/123456789abc/write/val1=12.34&val2=0.08&val3=23.2 |

| Figure 3. Monitoring device in the field |

| Table 2. Components cost of the monitoring device |
### Table 1: Component Costs

<table>
<thead>
<tr>
<th>No.</th>
<th>Component</th>
<th>Price (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5TE soil sensor</td>
<td>250</td>
</tr>
<tr>
<td>2</td>
<td>Circuit prototype: Arduino, GSM module, batteries</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>Weatherproof case</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>SIM card and GPRS service cost/year (pay per use)</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td><strong>Total:</strong></td>
<td><strong>306.5</strong></td>
</tr>
</tbody>
</table>

### 3. Conclusions

In this study, a cost effective soil monitoring system basing on open source hardware and GPRS connection was developed. Based on the result of the experiment, the system could operate correctly and data are stored in the cloud which can be used by farmers and researchers for supporting agriculture activities and research analytics. The system is designed for supporting farmers. The soil monitoring system has been used to increase the yield of crop and irrigation scheduling based on provided soil information. The soil data can be seen everywhere on a web page via the internet connection. Moreover, the total cost of the device is about $300 that is possible for farmers to invest for expansion of the precision agriculture. We are working on integrating an irrigation control system into this soil monitoring system in order to save the water use while maintain the production yield.

### References


