

Ubiquitous Monitoring of Agricultural Fields in Asia using Sensor Network

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Abstract

The introduction of ubiquitous computing technology in agriculture will allow the creation of a new agricultural system. To this end, a Japanese group has developed a number of new technologies over the past decade. One new technology is the “Field Server”. However, as a result of our long-term monitoring trials, some unexpected problems with the Field Server are now emerging. Here we describe the most significant points in the use of the Field Server based on our experiences in a rainfed paddy field in Thailand, and propose a new hybrid monitoring system incorporating a field network adapter that offers promise for safe agricultural production management in Asia.

Key Words

Field server, hybrid monitoring system, data logger, ubiquitous computing, sensor network.

Introduction

The Field Server is an automatic monitoring system consisting of a CPU (a Web server), an analog-to-digital converter, an Ethernet controller; sensors to measure air temperature, relative humidity, solar radiation, soil moisture, soil temperature, and electrical conductivity; and a CCD camera. It can transfer high-resolution pictures of fields and sensing data through Wi-Fi broadband networks (NARO, 2009). However, the Field server does not have a data logging function because it is designed to be used on the network. Therefore, we need to build a data logging system on the network in order to use the Field Server. So far, however, there has been little research on long-term monitoring in the field by the Field Server. We have installed Field Servers across Asia in fields of paddy rice, spinach, cabbage, and peanut since 2006 (Mizoguchi, 2008). Here we describe some unexpected problems in the use of the Field Server which were revealed by our long-term monitoring trials in a rainfed paddy field in Thailand. Then we propose a new hybrid monitoring system which is improved based on our experiences and show example data obtained with the new system.

Methods

Experimental site

We installed a Field Server on 2006 December 25 (Figure 1), three more on 2007 December 24, and another on 2008 December 26 in a rainfed field in Khon Kaen, northeast Thailand (16°27.657 N, 102° 32.443 E). The Field Servers are at most 700 m apart. With these Field Servers, we have been monitoring meteorological conditions (air temperature, humidity, radiation, wind velocity, precipitation) and soil information via soil sensors (moisture content, temperature, electrical conductivity), and collecting images of the site.



Figure 1. Field Server installed on 2007 December 24 (left) and Insect nest built on CPU board of Field Server(right).

Field Network System

The system installed in Khon Kaen comprises Field Servers, solar panels, a router, and an agent box (FSAB: Figure 2). In Thailand, all elementary schools have Internet infrastructure. We asked the school near the experimental site to rent us the Internet for our project. Data are stored via the Internet on a data server at Asia Institute Technology (AIT) in Thailand, the National Agriculture and Food Research Organization (NARO) in Japan, and The University of Tokyo (UT). Anyone can then download the data from our website (Mizoguchi, 2009) using ubiquitous tools such as a PC, mobile phone, i-Phone, Nintendo-DS, or PlayStation Portable.

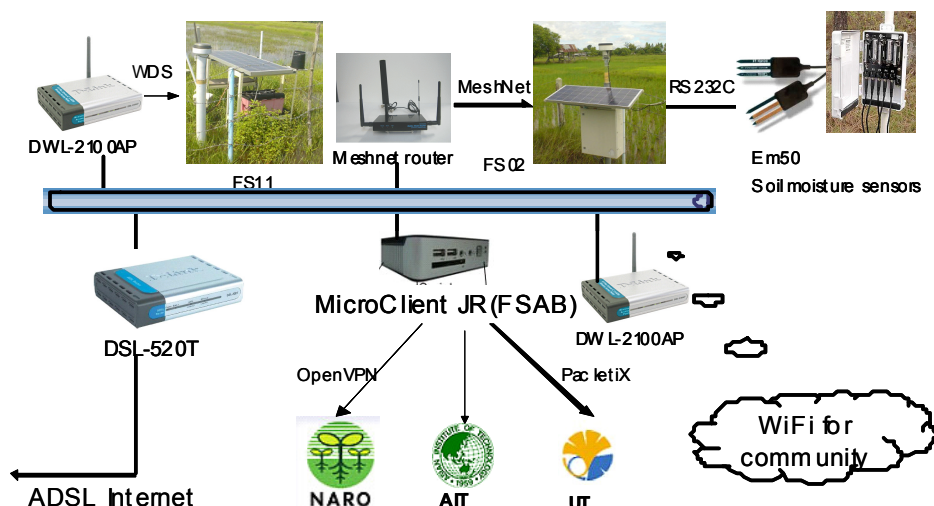


Figure 2. Field monitoring system in Khon Kaen, Thailand

Results

Hardware robustness

The three Field Servers installed in 2007 broke down after only half a year when the heat and ultraviolet light weakened their acrylic poles. The Field Server installed in 2008 broke down after only 4 months when insects built a nest on the CPU board (Figure 1). At present, only the Field Server installed in 2006 remains alive and keeps sending data. These facts tell us that we must take into account the characteristics of the field environment and choose appropriate materials when we set Field Servers in harsh environments.

Stability of the field network systems

The stability of the field network system depends on the field solar power supply, the antenna, the local electrical power supply, and the Internet connection. If any one of them develops a problem, we lose data. In fact, we often lost data on account of power outages at the school because of lightning strikes. On rainy days, the Field Server stopped sometimes because of solar power shortage or antenna power shortage. These experiences show that we need to install a data logger as near to the sensors as possible to hold the data.

Sensor calibration

The Field Server can be connected to various types of sensors, including weather multi-sensors (Visala Inc.), weather stations (Davis Inc.), and analog soil sensors (Decagon Devices Inc. 2009). Digital soil sensors such as the 5-TE can be also connected to a data logger (Em50; Decagon Devices Inc.) via an RS232C cable. Additionally, hand-made sensors can be connected as long as their output is a voltage. Sensors must first be calibrated, in particular soil moisture sensors, because the default equation given by Decagon Devices Inc. often differs from soil to soil. To solve this problem, Mitsuishi (2007) developed a simple method of calibrating soil moisture sensors.

Hybrid monitoring system consisting of a Field Server and a data logger

The Field Server is useful only when the Internet connection and the power supply are stable. However, such conditions are limited in rural areas, even in Japan. If a problem arises, we ourselves must visit the site on account of a shortage of Field Server engineers. Maintenance costs thus increase in proportion to the distance to the site. In fact, we have wasted a lot of time and cost maintaining the Field Servers. We conclude that we must incorporate a stable data logger in the field network. To this end, we developed a “field network

adapter”.

Field Network Adapter

The field network adapter box (FNA box; X-Ability Ltd.; Figure 3) is protected against the intrusion of solid objects, dust, accidental contact, and water in electrical enclosures at the level of IP65 (IEC 60529). It houses a Wi-Fi network adapter, a battery, a timer, and a charge controller. The Wi-Fi network adapter is a one-port device server that lets us connect serial devices to 802.11b/g wireless or 10/100-Mbps Ethernet networks (Grid Connect, 2009). The FNA box derives its power from a small solar cell panel (2 W) and can be connected to an antenna in case the Wi-Fi signal is weak. The timer switches the device on and off to save power. The device is normally turned on for 1 hour a day, which is long enough to address the data logger. Once the FNA box is connected in the field, we can download the data when the device is on by using the Network Adapter Manager on the Web (Figure 3). Images of the field are also viewable because the Field Server camera is connected to the same network.

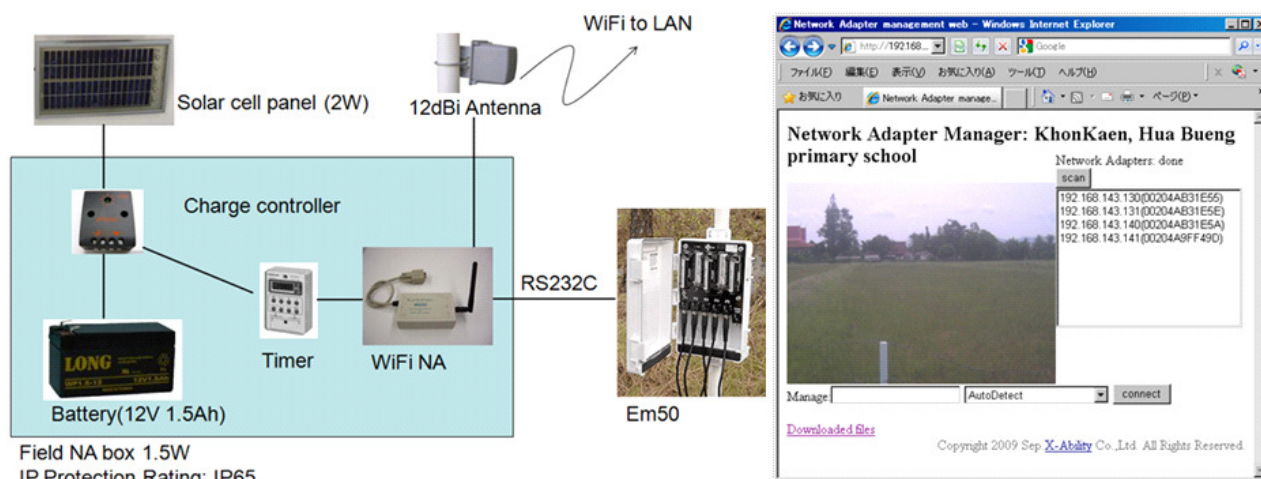


Figure 3. Field Network Adapter Box (left) and Network Adapter Manager on Web browser.

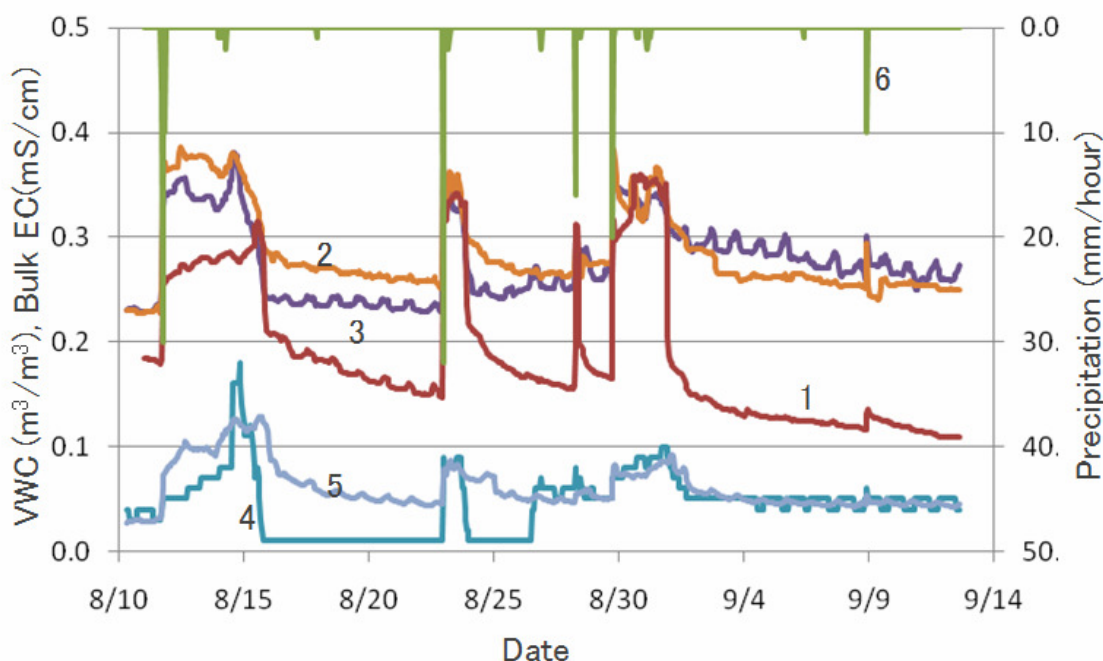


Figure 4. Changes in soil moistures, bulk electrical conductivity of soil and precipitation from Aug. 11 to Sep. 12, 2009 in a rainfed paddy field in Khon Kaen, Thailand. The numbers in the Figure denote the sensors we used. 1: Volumetric water content (VWC, m^3/m^3) measured by EC-5 sensor buried horizontally at the depth of 4 cm, 2: VWC (m^3/m^3) by EC-5 sensor inserted perpendicularly at the depth of 2-7 cm, 3: VWC (m^3/m^3) by 5-TE sensor inserted perpendicularly at the depth of 2-7 cm, 4: bulk electrical conductivity (mS/cm) measured by 5-TE sensor, 5: bulk electrical conductivity (mS/cm) measured by hand-made sensor, 6: precipitation (mm/hour).

Downloaded data - soil moisture, bulk EC and precipitation

Figure 4 shows an example of data downloaded from an Em50 data logger, showing changes in soil moisture, bulk electrical conductivity, and precipitation from 2009 August 11 to September 12 in the rainfed paddy field at Khon Kaen. The numbers in the Figure denote the sensors we used. Soil moisture is measured with two EC-5 sensors and a 5-TE sensor (Decagon Devices Inc.); A EC-5 sensor (1) is buried horizontally at depths of 4 cm, and the other EC-5 sensor (2) and the 5-TE sensor (3) are inserted perpendicularly at the depth of 2-7 cm. Bulk electrical conductivity is measured with a 5-TE sensor (4) and a hand-made sensor (5) of a pair of stainless steel rods inserted perpendicularly to a depth of 20 cm. Precipitation (6) is measured with an ECRN-50 rain gauge (Decagon Devices Inc.). Soil moisture and bulk electrical conductivity increased after rain. The horizontal soil sensor (1), measuring at a single depth, is more sensitive than the perpendicular ones (2, 3), which detects the average soil moisture over 2-7 cm.

Conclusion

A hybrid monitoring system consisting of a Field Server and a data logger connected by a field network adapter offers promise for safe agricultural production management in Asia. Although we have just started to test the system, stable and easy access to the data logger is reducing the worries that we felt before. However, there remain fundamental risks such as electric power outage and network disconnection. Consequently, we urgently need to train field network engineers to maintain the field monitoring system. In addition, we need to develop a more ubiquitous system based on the mobile phone system that is dependent on existing an Internet connection. Concern about the safety of imported food is increasing in Japan and a trial has started to show consumers a safe spinach field in Thailand (Honda, et. al, 2008). We hope that our new field monitoring system will help to bolster consumer confidence in food that is imported from other Asian countries into Japan.

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