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Ubiquitous Monitoring of Agricultural Fields in Asia for Safe Agricultural Production Management

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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.

Keywords : Field server, hybrid monitoring system, Field network adapter, data logger, ubiquitous computing, sensor network

Introduction

In recent years, the concept of food safety and confidence has become important in many countries. In particular, concern about the safety of imported food is increasing in Japan. Because most people don’t know where and how the food they eat is treated, they worry about food safety. For this reason, research on food traceability systems has started using IT (Koshizuka, et. al, 2005). However, it is still difficult to monitor all routes that foods follow. Therefore, we are developing a ubiquitous field monitoring system for safe agricultural production management to show consumers the starting and ending points of the food as a first step (Honda, et. al, 2008).

The introduction of ubiquitous computing technology in agriculture will allow the creation of a new agricultural system, which we call “ubiquitous-agriculture”. To this end, the National Agricultural Research Center in Japan has developed a number of new technologies over the past decade. One new technology is the “Field Server”, developed under the “Database-Model

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cooperation system" project of the Ministry of Agriculture, Forestry and Fisheries of Japan (NARO, 2007). 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 data logging function because it is designed to be used on the network. Therefore, we need to build data logging system on the network in order to use the Field server.

Because the Field Server is a relatively new technology, infrastructure to support it is still being developed. Fukatsu et al. (2006) developed the Agent system to collect data automatically. Honda et al. (2009) developed the Sensor Observation Service to collect Field Server data and publish it on the Internet, integrating Field Server and Web GIS data. Such user-friendly infrastructures make the Field Server easy for farmers to use.

So far, however, there has been little research on long-term monitoring in the field by the Field Server. The Data Integration & Analysis System (DIAS, 2008) aims to develop an information system for agricultural production management by integrating real-time monitoring data from farmland, the growing conditions of crops, meteorological data, weather predictions, and climate model predictions. The system will allow farmers to make improved management decisions, especially in regions susceptible to global warming impacts. In the DIAS project, we have installed Field Servers across Asia in fields of paddy rice, spinach, cabbage, and peanut since 2006 (Mizoguchi, 2008). 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, propose a new hybrid monitoring system of Field Server and an existing-stable data logger, and discuss the possibilities of the ubiquitous monitoring of agricultural fields in Asia.

Field monitoring trials

Experimental site

We installed a Field Server on 2006 December 25 (Fig. 1), three more on 2007 December 24 (Fig. 2), and another on 2008 December 26 (Fig. 3) in a rainfed field in Khon Kaen, northeast Thailand (16^{o}27.657 N, 102^{o} 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.

Fig. 1. Field Server installed on 2007 December 24

Fig. 1. Field Server installed on 2006 December 25

Fig.3. Field Server installed on 2008 December 26

Fig. 4. Insect nest built on CPU board of Field Server

Field Network System

The system installed in Khon Kaen comprises Field Servers, solar panels, a router, and an agent box (Fig. 5). 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 (Fig. 6).

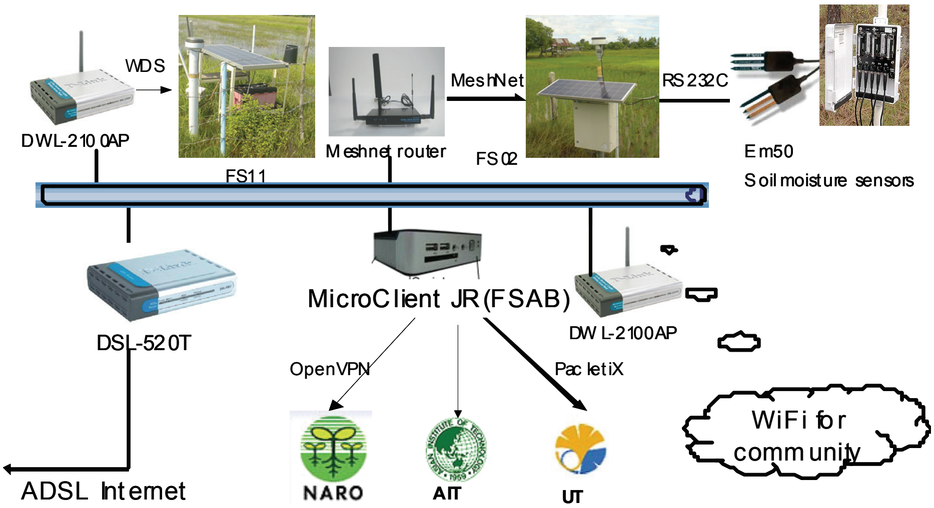

Fig. 5. Field monitoring system in Khon Kaen, Thiland

Fig. 6. Data download page for PC (left) and ubiquitous tools (mobile phone and Nintendo-DS) for data download (right). (Mizoguchi, 2009)

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 (Fig. 4). 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 system

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.; Fig. 7) 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 of 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 (Fig. 8). Images of the field are also viewable because the Field Server camera is connected to the same network.

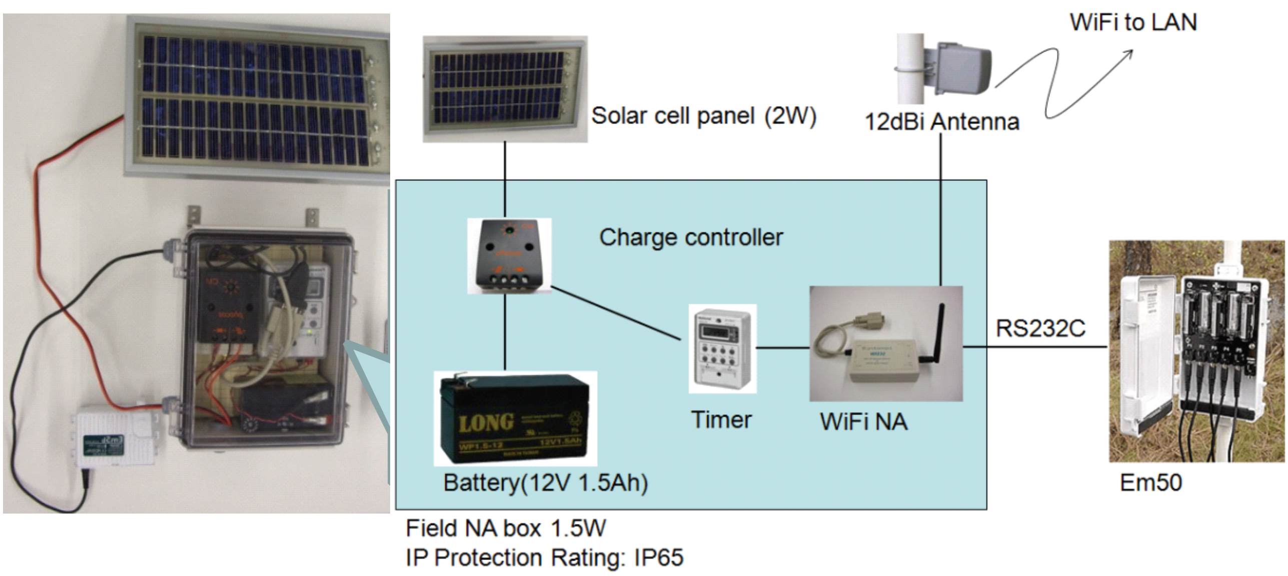

Fig. 7. Field Network Adapter (FNA) Box

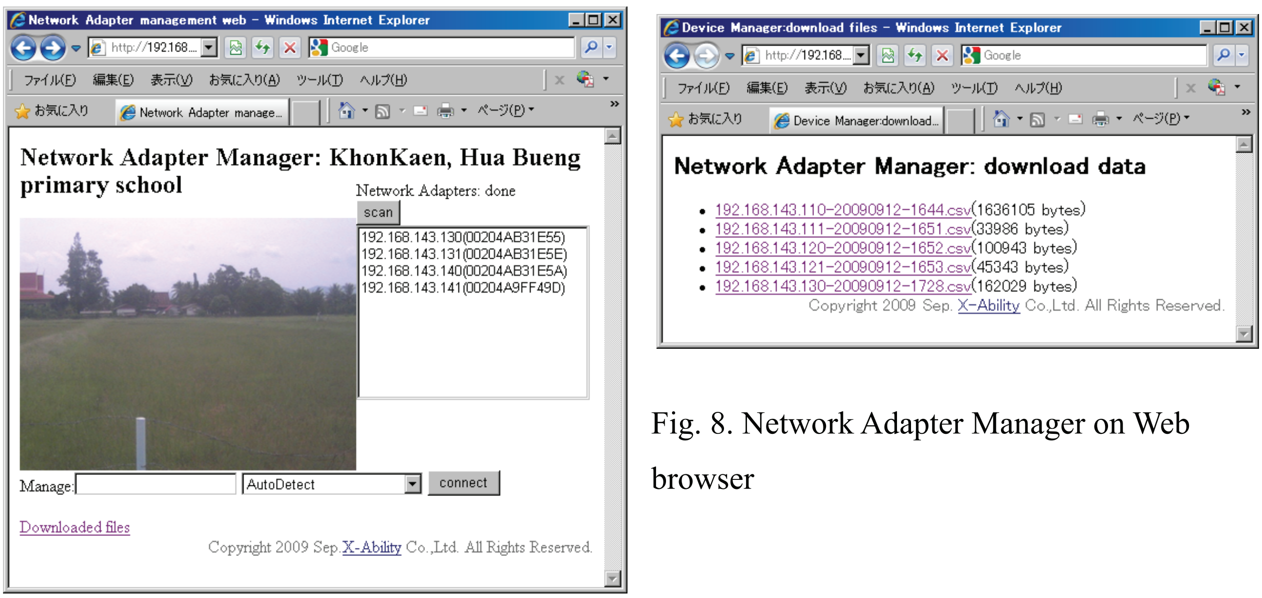

Fig. 8. Network Adapter Manager on Web browser

Downloaded data - soil moisture, bulk EC and precipitation

Figure 9 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 in Khon Kaen. The numbers in 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 below the surface. 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 that the perpendicular ones (2, 3), which detect the average soil moisture over 2-7 cm.

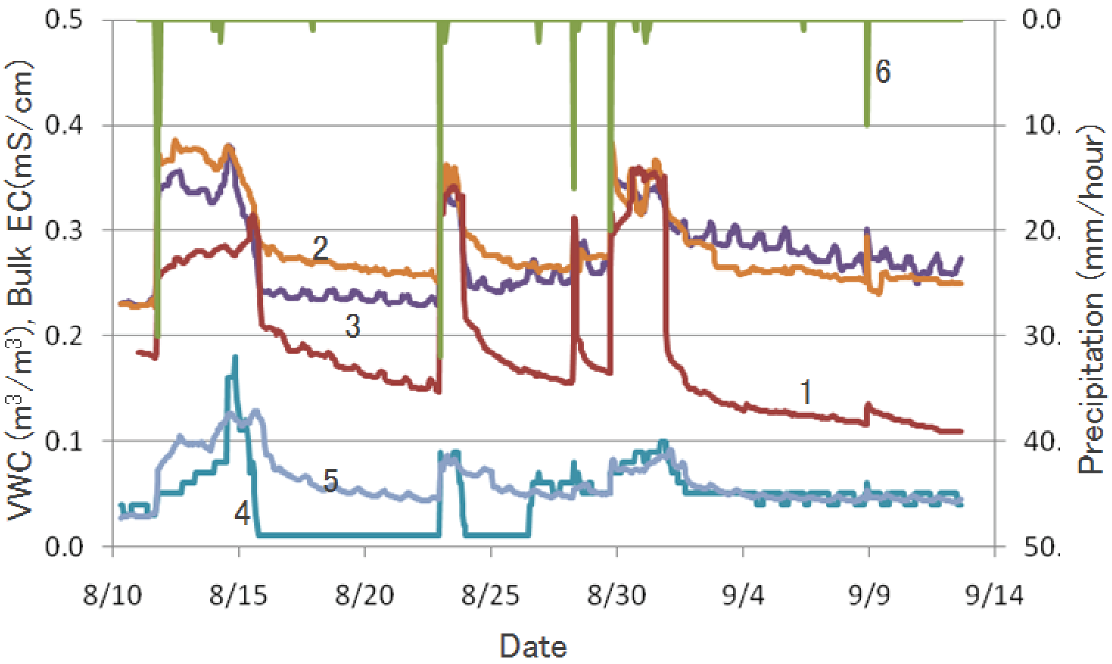

Fig. 9. Changes in soil moistures, bulk electrical conductivities of soil and precipitation from Aug. 11 to Sep. 12, 2009 in a rainfed paddy field in Khon Kaen, Thailand. The numbers in Figure denote the sensors we used. 1: Volumetric water content (VWC, m^3/m^3) measured by EC-5 sensor buried horizontally at the depth of 4 cm, 2: VWC (m^3/m^3) by EC-5 sensor inserted perpendicularly in the depth of 2-7 cm, 3: VWC (m^3/m^3) by 5-TE sensor inserted perpendicularly in 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)

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 Internet connection. We hope that this field monitoring system will help to bolster consumer confidence in food that is imported from other Asian countries into Japan.

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