Long-Term Monitoring System using Field Monitoring Servers

T.Fukatsu[1], M.Hirafuji[1], T.Kiura[1], A.Imada[2], and S.Ninomiya[1]

Abstract

In agriculture, it is important to easily monitor various types of field information. We propose and construct a long-term monitoring system using measurement equipment with built-in Web servers such as Field Servers. By building a Web server into measurement equipment, we can manage the equipment from any place at any time using very little effort. In order to operate this system, it is required a construct an agent program and a secure network. An agent program not only collects data periodically, but also controls equipment flexibly and cooperates with Web applications via a network. For managing the agent system effectively, we construct a network using VPN connections which enable secure access to remote places, or use a POST/FTP/Mail function. The actual use of the Field Server Agent System over long periods of time has demonstrated its effectiveness and reliability.

Keywords: Field Server, Agent, Web, Monitoring, Network, Internet

Introduction

In agriculture, the long-term monitoring of crop growth and the field environment is important for predicting growth, for pest control, and for quality management. Ordinary monitoring field data has so far been performed by collecting data periodically through the installation of a data logger, or by receiving data from meteorological survey stations. However, such monitoring is difficult to perform over long periods since collecting and arranging the data requires large effort on the part of a user in the field. Especially, it is essential that various types of information are provided in real time, and it is desirable that the user acts on the measurement data in order to prevent crop injury, pests, and diseases. This cannot be achieved using the conventional system. Some data loggers can transmit data in real time using a cellular phone or a transceiver, but the system using them requires exclusive use software and can't cooperate with peripheral equipment. In addition, a system has also become required that can treat large data for handling image sources (Kida *et al.* 2003). In the present paper, we propose a long-term monitoring system that utilizes a Web server for measurement equipment which can easily treat various data from any place at any time, and can reduce the amount of effort required of a user.

Measurement Equipment with Built-in Web Server

A Web server is software that can present Web information to a client based on TCP/IP. By building a Web server into measurement equipment, we can easily access and manage the equipment using a Web browser such as Internet Explorer, without installing exclusive software. It can operate stably because only simple

[1] Department of Information Science and Technology, National Agriculture Research Center, 3-1-1 Kannondai, Tsukuba, Ibaraki 305-8666, Japan, fukatsu@affrc.go.jp
[2] Ibaraki University, 3-21-1 Chuo, Ami-machi, Inasiki-gun, Ibaraki 300-3093, Japan

firmware is mounted on the inside, and yet it can respond to various intelligent operations from a computer via the network. Moreover, it can link with other Web servers and Web applications via the Internet. Through its use, we can construct an adaptable and flexible monitoring system which can be managed with little effort in a remote place.

In our previous work, we developed small monitoring robots called “Field Servers” (Fig. 1) which are equipped with a Web server and can use wireless LAN to provide a high-speed transmission network at a low price (Fukatsu and Hirafuji, 2003, He *et al.*, 2003). By using Field Servers as a sensor network, a massively distributed monitoring system can be constructed easily which can collect field information and control peripheral equipment via the network (Fukatsu *et al.*, 2002).

As measurement equipment using such a Web server, Web Camera is beginning to spread with high quality and low price according to advancement of IT. However, it can usually be accessed only to see real-time images, and it is difficult to extract useful information from them, to cooperate with other applications, and to perform long-term monitoring. Although some Web cameras can transmit image data automatically using FTP or Mail, no current receiving system can periodically process and store these data. Such cameras require a user to program exclusive software, secure storage device for the database, and manage the computer and network over a long period of time.

Thus, in the present paper we construct a long-term monitoring system that can respond to these issues, can reduce the amount of effort required of the user, and acquire useful support information using measurement equipment such as Field Servers which have built-in Web servers.

Field Server Agent System

While the measurement equipment with built-in Web servers such as Field Servers have the various features described above, they can be used only by being directly accessed by a user. Thus, an agent program is needed for collecting data periodically and for operating peripheral equipment automatically. In the case of Field Servers, it is possible to treat them with other Web servers and Web applications on the assumption that they can be accessed via the network. By constructing a general-purpose agent program on the network, we can manage Field Servers from anywhere without installing the program individually in the field. Moreover, if the computer which executes an agent program is equipped with a high performance CPU and a large database, it can respond to various intelligent operations via the network. In order to realize this system, we have constructed a Field Server Agent System written in Java, and which is operated based on a configuration file written in XML format (Fukatsu and Hirafuji, 2004).

The agent program is designed so that it may operate according to the command described in a configuration file. Only by changing a configuration file, a user can easily manage many Field Servers and peripherals, and also handle various Web applications via the network. It can easily and automatically cooperate with Field Servers and Web applications, for example, collecting temperature and relative humidity data from measurement equipment, inputting these data into a dew-point temperature calculation application on the Internet and obtaining the resulting data (Fig. 2).

Measurement data collected by an agent program is stored as a database in the XML format on the network, and it can easily connect to “MetBroker” (Laurenson *et al.,* 2002), a middleware for weather data that provides agricultural models with consistent access to many different weather databases. Several MetBroker-compatible models have already been designed and many of their applications can be used for agriculture involving on-site field information from the Field Servers’ databases.

Moreover, Field Servers can perform not only measurement but can also control and operate various equipment such as digital I/O, relay switches, DDS, FPAA, and so on (Hirafuji and Fukatsu, 2002). The agent system has an IF-THEN rule so that it can respond to such functions according to the situation. Using this system, we can establish complicated condition judgments such as operation at fixed times and control according to the value of a sensor (Fig. 3). These functions are an important aspect of the system.

Network Construction

In order for this agent system to work effectively, it is important to construct a network which can access any Field Server from anywhere. If the range of the network which can access Field Servers spreads with the field, local network, and Internet, it becomes unnecessary to install a computer for an agent program at the field locations. This reduces the amount of effort required of a user, and a user can collectively manage Field Servers from anywhere via the Internet. However, connecting directly without considering network security exposes the system to the risk of illegal access and the control of the Field Servers by unspecified persons. The proposed system thus requires the installation of security measures.

For this purpose, we developed a network using Virtual Private Network (VPN) connections, such as PPTP and SSL/TSL, which enable secure access to remote places (Fig.4). Although a PPTP connection needs a fixed global IP, it is easy to connect from remote place by simply installing a PPTP router. A SSL/TSL connection does not require a global IP, and its connection is more stable than PPTP but its throughput is lower and its setting on Linux is difficult. The network has a high level of robustness because it can access Field Servers by using either PPTP and SSL/TSL or both (Kiura *et al.*, 2002). In this system, they can be accessed from elsewhere using a VPN connection by only installing hardware that has VPN functionality, such as a router or a mini-server. An agent program can access and control Field Servers safely from a remote place through the VPN router of these sites, and the identity of the agent system is confirmed by the VPN network system.

In some network environments, it is difficult to use VPN connections on account of local considerations such as severe security in a company, a low-speed transmission network, and dial-up connection. An agent system can not only gain access via a VPN connection but can also receive one-way data by writing to the bulletin board using a http POST function and sending via a FTP or Mail function. In the case of a severe network condition on the local side, the system monitors these output data from the local side in order to manage the agent system (Fig. 5). If an agent program can also be installed in a local side, this program can output monitoring data by proxy even if there is no POST/FTP/Mail function in the Web server. Moreover, by coordinating local agent programs and the Field Server Agent System, data loss problems can be avoided in the setting in which the local agent operates when the VPN connection encounters problems.

Results and Discussion

In order to test the performance of the Field Server Agent System for long-term monitoring, the agent system installed in our laboratory (NARC, Japan) has been used to monitor and control Field Servers installed in various places. According to a user's request, a site for data collection has been added by creating only a configuration file. Approximately 20 Field Servers situated in various parts of Japan are in operation, and approximately 10 others in the United States, Denmark, China, and Thailand are also operating. The agent system has performed reliably for more than two years since February of 2002.

These stored data can be plainly displayed by accessing not only MetBroker but also Web pages which the agent program creates with the function of easy handling to spreadsheet software such as Excel, and easy accessing to real time data by cellular phones which can use the Internet such as i-mode. As regards image data, the agent program also creates Web pages in which a user can easily search out useful image data from vast database. This Web page is displayed with serial image data which is thumbnailed for reducing capacity, while original image data can be easily accessed by clicking thumbnailed image data which is linked to it. Therefore, a user can inspect a moving image by few network loads and view important images with high resolution (Fig. 6). These Web pages are open to the public at http://model.job.affrc.go.jp/FieldServer/

Use of the Field Server Agent System in managing data over long periods of time demonstrates its capabilities as well as its reliability. By making a request to the agent system, the user of Field Servers can utilize the applications of the agent system and MetBroker with little effort about managing a computer to manipulate an agent program and a storage device for a database. At the same time, it provides an advantage for us in collecting many fact-data which is important in agriculture for data mining by offering the agent system world-wide.

The system with a built-in Web server is desired for use in various areas such as crop management, field surveillance, management support of domestic animals, and traceability. Up to now, many useful data has become unavailable for legacy problem about outdate equipment and the lack of qualified technicians. By utilizing the Web, databases can be shared, and many models and Web applications can be developed and utilized in a variety of situations.

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Figures

Figure 1. A standard Field Server. Field Servers can be equipped with monitoring sensors and control switches.

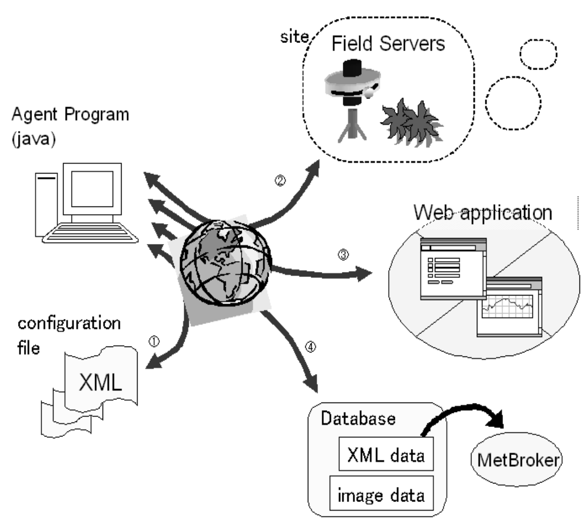

Figure 2. Architecture of the Field Server Agent System. The system is composed of an agent program, configuration files, Field Servers, databases, and applications.

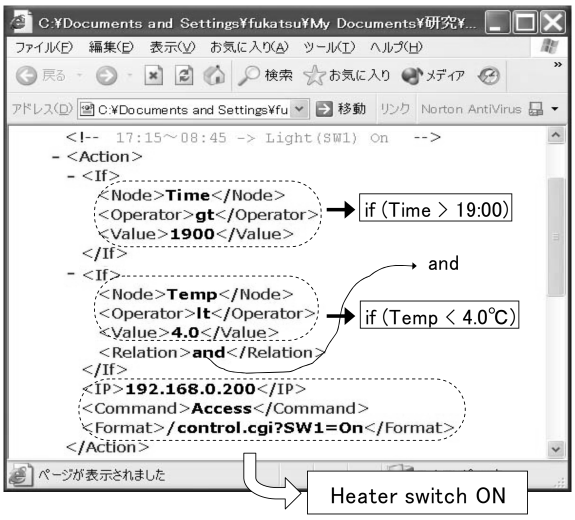

Figure 3. XML of a sample IF-THEN rule. The XML describes the operation of turning on a heater if the temperature falls less than 4°C after 19:00.

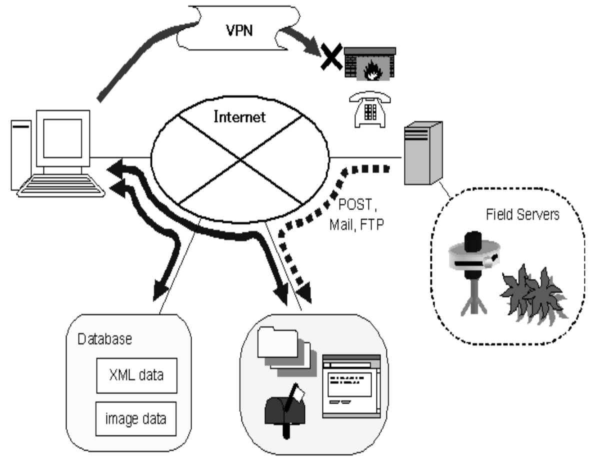

Figure 5. A construction of the agent system without VPN connection. An agent program receives one-way data by the POST/FTP/Mail function

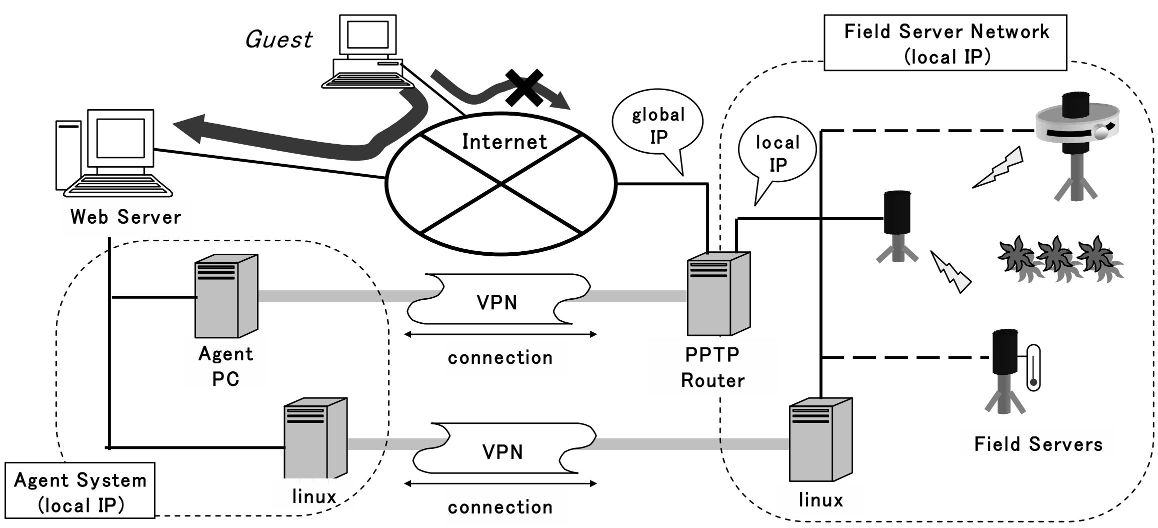

Figure 4. A standard VPN network for Field Servers. The network has strong robustness because it can access Field Servers using either a PPTP or SSL/TSL VPN or both.

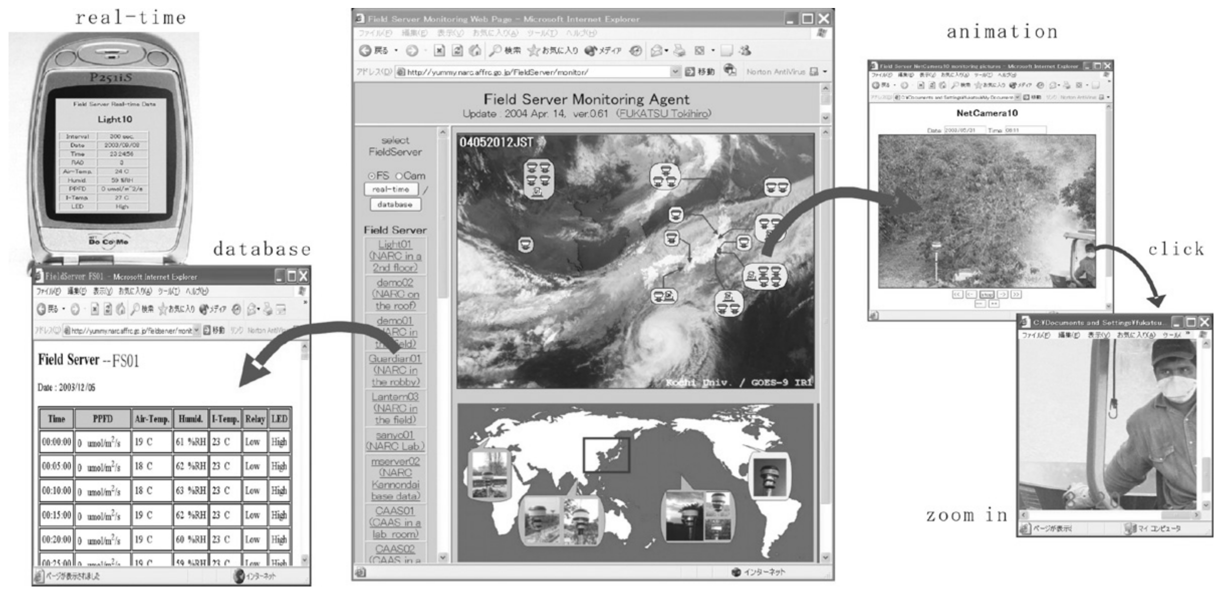

Figure 6. Web pages showing monitoring results. An agent system creates Web pages for displaying image data, stored data and real-time data on PDA.