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A FIELD IMAGE MONITORING SYSTEM BASED ON EMBEDDED LINUX

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ABSTRACT: Demands for real-time field monitoring systems are increasing in order to pass good agricultural cultivation practices down to future generations. In this study, a low cost and robust field image monitoring system was developed for acquiring real-time conditions from remote sites. The system consists of inexpensive commercial USB devices and an embedded Linux based broadband router equipped with some USB ports. A 3G USB modem dongle and data communication were used to access the Internet. The total cost of the system was almost 300 US dollars. Field experiments showed that this system met most of the requirements for field image monitoring in agriculture. In our research, the field image monitoring system was built using a WL-500gP v1 with a USB port as a CPU board, using embedded Linux and various USB devices. As a result of field experiments in which this system was installed outdoors, it was possible to demonstrate that it can withstand even high-temperature conditions, in which the interior of the system enclosure reaches 50 °C, as was the case during the 6-month installation period which included the summer. In addition, this system can connect to the network using cellular phone communication even in an area as a field where a wired network connection cannot be used. That is a gateway of the network in the field.

Keywords: Embedded Linux, USB, Sensor network, Image capturing, Field monitoring system

1. INTRODUCTION

Japanese agriculture has various problems such as a decrease in cultivated land, an increase in abandoned agricultural land, a decrease in agricultural workers and an aging population. For example, the number of key farmers has decreased significantly compared to 10 years ago, and 65% of them are over 65 years old [1]. Since many of the agricultural labor force is thus elderly, it is expected that the rapid decline of the agricultural labor force will occur in the near future. In addition, the self-sufficiency of food self-sufficiency on the calorie supply basis is about 40% in the past 20 years. This figure is the lowest among major developed countries, Japan is the world's largest agricultural importing country.

It is necessary to train and secure agricultural workers to deal with these agricultural problems in Japan, but countermeasures are still insufficient. One such countermeasure is the conversion from traditional "empirical agriculture" that has been conventionally done to "scientific agriculture" based on theory and data. In order to collect useful information cultivated in "empirical agriculture" and practical tips etc. as data and to convey it to the next generation, the need for data collection in the field is increasing.

In addition, in order to suppress the occurrence of insect damage and diseases, it is necessary to be able to obtain various types of information occurring in the agricultural field in real time [2]. Therefore, there is a growing demand for a field monitoring system that gathers data generated at agriculture sites in real time and transfers them to remote locations.

2. SENSOR NETWORK IN AGRICULTURE

A field server [3] is a typical monitoring device in the agricultural field. It is a compact monitoring robot that modulates sensors, computers, and communication functions, and can measure various physical properties such as temperature, humidity and soil moisture with specific sensors. The measured value is stored in a separately prepared server and can be made public through the Internet. In addition, since it has a relay function of wireless LAN, it can be used as a sensor network node [3]. Because of their diverse functions, field servers are used in many studies, but due to the price and complexity of the operation, they are not widely used by farmers.

For this reason, lower prices are important for the spread of field monitoring systems. One means of lowering prices is to narrow down to a single function, and the image acquisition function is widely adopted because images can contain much useful information such as the on-site situation and the weather. For example, Nakamura (2006) [4] is developing a monitoring system installed in a greenhouse to acquire temperature and images in real time. In this system, an image including a display of a commercially available digital thermometer is acquired by an inexpensive network camera and transferred to the server by FTP. Temperatures are read and stored by image analysis performed at the server. This system is easy to introduce and can be built at a low cost, but there remains some uncertainty about its durability for outdoor use.

The Live E! Project [5] aims to share all environmental data digitized by sensors with network technology, in order to realize a new open information platform [6]. In order to install a large number of sensors and carefully acquire a wide range of environmental data, they have developed a system called Digital Multi Box, and they monitor over 100 environmental data in 12 countries around the world. They have also developed an embedded system based on a weather station, but it is still expensive.

These field monitoring systems use the Internet to provide information in real time. However, when using these systems at agricultural sites, the question of how to obtain an Internet connection in the environment of the field emerges. For example, in the case of a field server installed in an orange farm as part of the Kumano Kanayama pilot, since it would have required thousands of USD as an initial investment to use the wired Internet connection service, satellite communication is used instead.

Based on the above, in this research, the following three items are set as conditions necessary for the system's application to agriculture, and a field image monitoring system that satisfies these conditions was constructed.

- Low price
- Durability to field conditions
- Secure data communication route outdoors

For this, the key technology is the embedded Linux described below.

3. EMBEDDED LINUX

Embedded systems are computer systems developed to provide a small number of functions to electronic devices, and in recent years have been widely adopted in automobiles, routers, home electronics, etc. Also, embedded systems have strict resource constraints intended for cost reduction, and it is strongly required to use processors with low processing capacity and reduce the amount of memory used [7].

Systems are becoming larger and more complicated in response to higher performance, complexity, digitization, and networking of devices to be controlled by embedded systems. For this reason, some embedded systems incorporate an OS for system management and control in the embedded system. ITRON, VxWorks, Nucleus PLUS, QNX, Windows CE, and Lynx OS are examples of famous embedded OS. Embedded Linux is also one of them.

Embedded Linux has been developed for computers with a small number of resources like the above embedded OS, but the basic structure is the same as the general Linux distribution. For this reason, embedded Linux has the advantage that an experienced Linux user can easily use it by making full use of his experience, and a package system is adopted to which it is easy to add functions. In addition, some embedded Linux is released for free. In this research, OpenWrt, which is provided for development environments among embedded Linux, was used for the field image monitoring system. Features can be added by the package system, but the number of published packages is much less than the general Linux distribution for PCs. Software required for this system, such as image acquisition software, was not included in OpenWrt. For this reason, image creation software packages for OpenWrt and packages of original programs were made by cross-compiling.

4. SYSTEM COMPONENTS

Table 1 shows the equipment constituting the field image monitoring system developed in this research. For waterproof/dustproof installation in the field, these devices were placed in a plastic container.

Table 1 List of system components

Device	Product name	Property
CPU board	Asus WL-500g Premium v1 (WL-500gP v1)	Wireless router USB 2.0 port x2
USB camera	Logitech QuickCam Orbit AF	UVC 2 million pixel sensor
USB modem	FOMA A2502	HSDPA
USB hub	Sanwa 225GBK	4 ports expansion
USB memory	Buffalo RUF2-K4GL	4 GB split into ext3, swap
USB hygrometer	Strawberry Linux USBRH-FG	USBRH driver

4.1 CPU Board

Ito et al. (2006) [8] installed NAS equipment in the field as an inexpensive compact computer and conducted data collection experiments in the field. It was found that the HDD in the NAS device could not endure high temperatures for long periods. Therefore, in this system, an ASUS WL-500g Premium v1 (WL-500gP v1), which does not have high-temperature sensitive parts such as the HDD, is used as the CPU board of the field monitoring system.

The WL-500gP v1 is a commercial wireless broadband router sold at around 100 USD. It consists of a 266 MHz Broadcom CPU, 8 MB flash ROM, 32 MB RAM, and has two ports for USB 2.0. As mentioned above, no HDD is installed, and the software etc. are all stored in memory. Therefore, it is considered to be more durable than general PCs and capable of being used for a long time in the field. In addition, it is clarified in the community that the WL-500gP v1 is capable of installing OpenWrt.

4.2 USB Camera

For field monitoring by images, a USB camera was used in this system. Although the resolution of a USB camera is generally lower than that of a digital camera or a single lens reflex, it has advantages such as low price, high durability and program controllability. In this research, a Logitech QuickCam Orbit AF (Qcam) was used.

Qcam is one of the best performing models among the commercially available USB cameras. Although it is in a relatively expensive class of USB cameras, it has an image sensor of 2 million pixels and has a high resolution of 1600×1200 pixels. For recognition of the Qcam on Linux, a UVC driver corresponding to V4L2 API is used, but many image acquisition software is compatible only with V4L1. In this research, fswebcam, which is image acquisition software compatible with a few standards, was used.

As mentioned above, OpenWrt did not provide image acquisition software, so a package for OpenWrt with associated libraries was made.

Immediately after installation, Qcam's highest resolution image file could not be obtained. This was due to the lack of the main memory capacity of the WL-500gP, which is the processing area, so it was attempted to expand the processing area by mounting a part of the USB flash memory in the Swap area. Also, since the WL-500gP v1 capacity itself is also small, the remaining area of USB flash memory was used for data storage.

4.3 Communication Card

In order to remotely view data obtained by field monitoring in real time, an Internet connection is important. However, it is difficult to obtain an Internet connection in environments far from private houses. Even if you can connect to the Internet via a cable from a private house, there is a possibility that the wire may be disconnected. Also, in field experiments conducted at the Coffee Garden in Hawaii, a great deal of labor was required, so wired connections have been shown to be inappropriate for building sensor networks [9]. Even when using a wireless LAN, if the system is far from a point where it can be connected to the Internet, a relay point needs to be set up. Therefore, in this research, FOMA A2502 HIGH-SPEED (A2502) was used as a data communication device by using data communication for a PC via a mobile phone communication network.

The A2502 is a data communication device that can be connected directly to the USB terminal of a personal computer and can perform data communication in both the FOMA high-speed area and the FOMA area. In the FOMA high-speed area, a maximum data reception of up to 7.2 Mbps is possible. However, the service provided by NTT Docomo is compatible only with Windows and Mac computers, so special software for connecting is necessary. In this research, the eAccess corporate service was used for the field monitoring system.

4.4 USB Hygrometer

The USB hygrometer made by Strawberry Linux Corporation uses Sensirion's SHT11 chip to measure the relative temperature and humidity. It has a temperature accuracy of ±0.4°C and relative humidity accuracy of ±3%. As mentioned above, since one of the main objectives of this research is to improve the durability of the system, continuous measurement of the temperature inside the box and of humidity is carried out, and in order to show the drive temperature range of these periods, the USB temperature/humidity Total was used.

This USB thermometer is compatible with Windows, but drivers for Linux were developed by volunteers [10]. Thus a package for OpenWrt was made by us. Temperature and humidity measurements were collected by the script and performed every 5 minutes using the cron.

5. SYSTEM FLOW

A schematic diagram of the system developed in this research is shown in Fig. 1.

Data in the field were independently obtained by scripts for image acquisition and scripts for temperature and humidity measurement, collected at regular intervals by the cron. The collected data was temporarily stored in the WL-500gP v1 RAM in consideration of the limitation on the number of times of writing to the USB flash memory, and copied to the USB memory every several hours and at the same time forwarded to the remote server. Since the capacity of the WL-500gP v1 is small, the temporary file on the WL-500gP v1 was deleted when copying to the remote server was successful. If it failed, it was set so that it would be transferred together at the next transfer.

6. RESULTS AND DISCUSSION

6.1 Field Experiment

In order to verify the stable operation of the system, the first field experiment was carried out in the period from August 1, 2008, to January 27, 2009, when it was collected for maintenance. Experiments were conducted at Mie University's experimental field, and the system was installed under direct sunlight assuming a similar environment when actually installed in the field. As a result, it was confirmed that

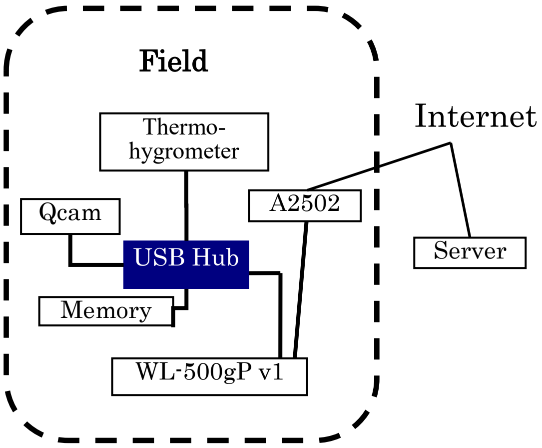

Fig. 1 Schematic drawing of the field image monitoring system

it can operate without thermal runaway etc. in the 6 months including the summer season.

The second experiment began on August 28, 2009, and ended at the end of October 2009. In this second experiment, the quality of the acquired images was focused using a system that was improved after the first experiment.

6.2 System Cost

As shown in Table 2, the price of the field image monitoring system in this study was about 300 USD, not including the data communication charges. The data communication fee seems expensive, but it is inexpensive compared to other data communication options such as satellite communication, which costs 600 USD a month. Furthermore, since other providers are starting mobile phone communication services at a cheaper price, it is thought that the data communication charges will decrease in the near future.

Table 2 Total amount of field image monitoring system

	Initial cost	Running cost
CPU board	Around 100 USD	
USB camera	100 USD	
USB hygrometer	50 USD	
Data communication charges		95 USD/month
Other	Around 50 USD	
Total	Around 300 USD	95 USD/month

6.3 Durability in Field Setting

Figure 2 shows the changes in temperature and relative humidity in the plastic container used for this system during field experiments from 24 hours from noon on August 19, 2009. For the measurement, we used the developed system and the USB hygrometer. In Fig. 2, the RRDtool [11] is used to make the data transfer destination server. As soon as the temperature and relative humidity data measured in the field are transferred to the server, a graph is made by the script and released on the Web. For this reason, it is possible to monitor the condition of the field with a browser, and if there is no change in the graph, it is easy to determine remotely that a problem with the system has occurred.

As can be seen from Fig. 2, the maximum temperature in the plastic container reached 50 °C, and it was 45 °C or more until 17:00. According to the Meteorological Agency HP [12], the maximum day temperature at the Tsu Meteorological Observatory was 30.3 °C on the same day, and the daytime highest temperature in August 2009 always exceeded 30 °C. From this fact, it is considered that the field system was exposed to an environment of 40 °C or more during August for several hours and experienced as much as 50 °C or more. In fact, August 2008 was hotter than 2009, and there were days when 36.9 °C was recorded, so it is inferred that in the first field experiment the system was operating under higher temperature conditions. As a result of this experiment, it was possible to demonstrate that the system was sufficiently durable for the field setting, as it operated stably for 6 months.

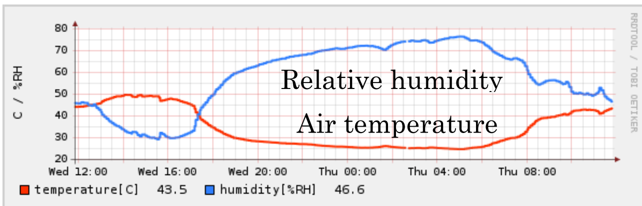

Fig. 2 Changes in temperature and humidity in the system enclosure from 1200 for 24 hours on August 19, 2009

6.4 Securing Data Communication Paths Outdoors

The field image monitoring system developed in this research has three ways of connecting to the network: wired connection, wireless connection by WiFi, and mobile phone communication. Since WiFi has not been used/evaluated yet, it is omitted, but by having multiple network connection methods like this, it becomes possible to install the system on a case by case basis. For example, when installing the system in a place where the wired connection is available, it is easy to set up and operate the system cheaply. Also, even in the case where the wired connection cannot be used, if it is located in an area where cellular phone communication is available, it is possible to connect to the Internet by mobile phone data communication via the A2502. This connection method was effective even in the mandarin orchard of the Kumano Kanayama pilot where no wired connection was available. Also, the transfer rate to the server when mobile phone data communication was used was able to transfer a file of 400 KB, the average size of 2 million pixel images that can be acquired by this system, in about 6 seconds. Therefore, it was found that the means of transfer used in this system was sufficient for the acquired image transfer and that by using the data communication it is possible to secure the communication path in the field to some extent.

6.5 Image Acquisition

In the first field experiment, an inexpensive USB camera with a maximum resolution of 640×480 pixels was used. However, the image obtained was almost saturated, and it was impossible to improve the situation just by changing the parameters of the driver. For this reason, the USB camera in the second field experiment was modified and Qcam was used.

By using Qcam, the image quality saturation problem was solved. Although it has an image sensor with 2 million pixels and can obtain images with a maximum of 1600×1200 pixels, due to the memory shortage of the WL-500gP v1, initially only low-quality images could be acquired. But it was possible to obtain a high-resolution screen as shown in Fig. 3 by expanding the processing area with the USB memory. It was presumed that it would be useful in image processing etc. because it has a higher resolution than a general USB camera.

Fig. 3 Best quality image obtained with Qcam

6.6 Performance Evaluation of USB Camera

Since the inexpensive camera used before was saturated under strong sunlight, it was difficult to acquire an image that can determine the outdoor situation no matter how to set it on the software side. For this reason, in Qcam, a performance evaluation experiment was conducted to verify to what degree of illumination would saturate the captured image.

In this evaluation experiment, color charts were used, with fluorescent lamps changed in five stages from 100 lux to 500 lux in the shooting darkroom whose illuminance can be adjusted up to 500 lux. In addition, a color chart was shot even in the shade (2200 lux) to evaluate the performance in outdoor use. The color chart taken was as shown in Fig. 4. When comparing the two images, it can be determined that the red section of the color chart of 2200 lux is close to the saturation state.

Based on the obtained image, the RGB values in each section were calculated by the self-made program provided by Mie University Bioinformatics Laboratory. This is summarized in Fig. 5. Since the RGB values of the red partition are all close to the maximum value of 255, it can be numerically determined that it is saturated one step before this. However, it can be seen that the R-value hardly changes in the red zone. The G value of the green section is also the same. In addition, the blue section has not changed much between 100 lux and 2200 lux. From this, it is considered that automatic adjustment is performed so as not to saturate the images in the USB camera.

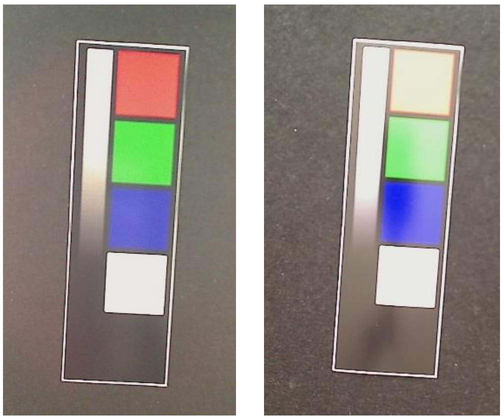

Fig. 4 Color chart photographed image (left: 100 lux right: 2200 lux)

7. CONCLUSION

In this research, a WL-500gP v1 with a USB port was used as a CPU board, and a field image monitoring system was constructed using embedded Linux and various USB devices. As a result of field experiments in which this system was installed outdoors, it was possible to demonstrate that the system can operate even under high-temperature conditions where the interior of the system enclosure reaches 50 °C, as occurred during the 6-months installation period including the summer. In addition, this system can connect to the network using cellular phone communication even in an area like a field where no wired network connection is available, and it was able to become a gateway for the network in the field.

Therefore, in the system developed in this research, a field image monitoring system satisfying the three conditions of i) low price, listed as a condition necessary for system application to agriculture, ii) durability against field conditions and iii) an outdoor data communication route, was successfully established. Since the technology used in this system is by no means specialized only to agriculture, it can potentially be applied also in many other problems such as the observation of ecosystems or monitoring of slope disaster, for example.

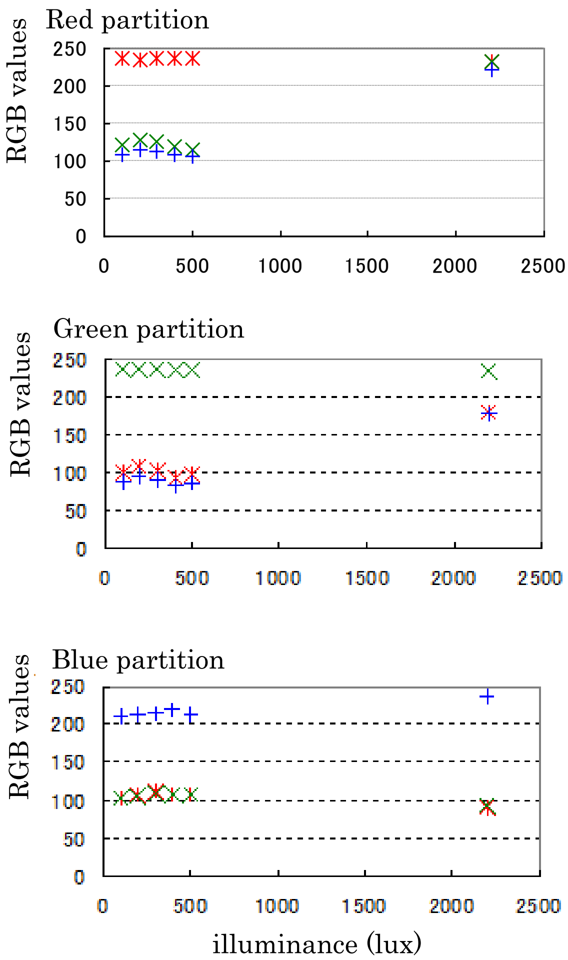

Fig. 5 Relationship between RGB values and illuminance change in each color section on the color chart (*: R value, ×: G value, +: B value)

ACKNOWLEDGEMENTS

This article is a reprint of a paper from previous proceedings [13]. About 10 years have passed since this proceedings was printed. Now, calls for the spread of Information and Communication Technology (ICT) are increasing [14]. However, the distribution of ICT in actual fields is still very small. In particular, the use of image information on farms, as introduced in this paper, remains invisible. One of the most important tasks for farmers is to observe the growing condition of crops. Therefore, this research is expected to contribute to agriculture. Conversely, some of the authors who are not directly involved in agriculture do not see the merits of using image information well. For that purpose, we introduced the research contents here and hoped to receive opinions from many readers.

We express my gratitude to Prof. Atsushi Hashimoto and Mr. Kentaro Furusawa of the Graduate School of Biological Information Engineering Laboratory of Mie University (Mie, Japan), for providing the darkroom and analysis software for the performance evaluation experiment with the USB camera.

8. REFERENCES

[1] Ministry of Agriculture Forestry and Fisheries (2016), FY2015 Annual Report on Food, Agriculture and Rural Areas in Japan. http://www.maff.go.jp/e/data/publish/attach/pdf/index-38.pdf pp.19 (Accessed March 29, 2019)

[2] Fukatsu T. and Hirafuji M., The Agent System for Field Monitoring Servers to Construct Smart Sensor-Network, Proc. 5th Int. Workshop on Artificial Intelligence in Agriculture, 2004, pp. 1-5.

[3] Field Server: Home, http://model.job.affrc.go.jp/FieldServer/default.htm (Accessed September 9, 2009)

[4] Nakamura N., Construction of a field image monitoring system and an application of image recognition technology, 4th WCCA, 2006, pp. 78-83.

[5] Live E! ~ Environmental information on living Earth ~ (in Japanese) http://www.live-e.org/en/index.html (Accessed September 9, 2009)

[6] Ochiai H., Matsuura S., Yamanouchi M., Aiming for New Development of Sensor Networking - Live E! Workshop in APNG Camp Activity Report, Information Processing, Vol. 50, No.1, Jan. 2009.

[7] Takada H., Syukuguchi M., Nankaku S., and Kishida M., Basic Real-time OS and Embedded Technology – Practice μ ITRON Programming (in Japanese), CQ Publisher, 2003.

[8] Ito R., Hirozumi T., and Nagaya Y., Modification of Inexpensive NAS Devices for Field Monitoring, Proc. 4th World Congress on Computers in Agriculture (WCCA), 2006, pp. 72-77.

[9] Ito R. et al., Soil Moisture Monitoring Using Near-infrared Sensing Technique and the Internet

in a Coffee Plantation Field, Proc. AFITA/WCCA Joint Congress on IT in Agriculture, 2004, pp. 463-469.
[10] USBRH driver for Linux, http://green-rabbit.sakura.ne.jp/usbrh/ (Accessed August 14, 2018).
[11] RRTtool, http://oss.oetiker.ch/rrdtool/ (Accessed August 25, 2009).
[12] Japan Meteorological Agency, http://www.jma.go.jp/jma/index.html (in Japanese) (Accessed September 7, 2009)
[13] Ito R. and Yamaguchi C., A Field Image Monitoring System Based on Embedded Linux, 52nd Automatic Control Joint Lecture November 21 and 22, 2009 (Osaka University)
[14] For example, Wakasugi K., Suzuki S. and Maruyama A., anticipated effects of advanced use of on-farm remote automatic water management system on areal paddy culture, water, land and environmental engineering, 15-18 (2018), (in Japanese).