A Study on the Implementation of Pigpen Management System Using Wireless Sensor Networks

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Abstract. The wireless sensor networks (WSN) technology based on low power consumption is one of the important technologies in the realization of ubiquitous society. When the technology would be applied to the agricultural field, it can give big change in the existing agricultural environment such as livestock growth environment, cultivation and harvest of agricultural crops. This research paper proposes the 'Pigpen Management System' using WSN technology, which will establish the ubiquitous agricultural environment and improve the productivity of pig-raising farmers. The proposed system has WSN environmental sensors and CCTV at inside/outside of pigpen. These devices collect the growth-environment related information of pigs, such as luminosity, temperature, humidity and CO2 status. The system collects and monitors the environmental information and video information of pigpen. In addition to the remote-control and monitoring of the pigpen facilities, this system realizes the most optimum pig-raising environment based on the growth environmental data accumulated for a long time.

Keywords: WSN, Ubiquitous, u-IT, Agriculture, Pigpen.

1 Introduction

The wireless sensor networks technology based on low power consumption is one of the important technologies in the realization of the ubiquitous society. It is applied and utilized in various fields such as environment monitoring, disaster control, logistic management and home network [1][2]. As the ubiquitous technology such as wireless sensor network technology has brought big change to other industries and daily living, it can also be utilized in the agriculture and livestock industry in various ways [3].

The ubiquitous agriculture has its purpose on enhancing the productivity by combining IT technology with agriculture, examining the safety of agricultural crops by systematically managing the distribution/consumption of crops and making the process of distribution/consumption transparent [4].

For instance, an unmanned control device is installed in the facility house producing agricultural products. The device automatically measures the environmental change

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factors of the crop, such as temperature, humidity, ammonia gas, CO2 and the weather. The measured information is saved in database and utilized in the agriculture. Through this process, it is possible to reduce the material input for crops growth such as fertilizers and chemicals, decrease the production cost by making the most optimum growth environment and enhance the productivity [5][6].

The ubiquitous technology is also effectively used in the livestock-raising such as pig-raising or chicken-raising. For instance, RFID technology and WSN technology are used in the pig-raising to manage the feeding of pig-individual, pigsty environment and pigs growth tracking. Mobile device gives alarm when there is an abnormality in the pig-individual so that farmers can take immediate action [6].

Recently, domestic pig-raising industry faces a face-to-face duel with pig-raising advanced countries because of rise in the feed cost and the execution of FTA [7]. Also, the mortality rate caused by wasting diseases increases and production cost goes up together, giving double difficulties to pig-raising farmers. Accordingly, the productivity increase and high quality pork production became the essential tasks of pig-raising industry [8].

In order to cope with this issue, it is urgently required to secure the scientific and systematic pig-raising technology combining current u-IT technology with pig-raising industry, which is the primary industry.

This paper proposes 'Pigpen Management System' using wireless sensor networks, which is an management system applying the WSN technology to the pig-raising environment management and control.

The proposed system enables the monitoring of pigpen environment and the control of pigpen facilities. Through these, the optimum pig-raising environment can be maintained, productivity can be increased and producer convenience through remote/automatic control can be also achieved.

This research paper is comprised of followings. Chapter 2 will explain the system structure and service process of pigpen management system using wireless sensor network. Chapter 3 will explain the system operation result. Chapter 4 will compare and analyze the experiment result. Finally, Chapter 5 will give conclusion to close the research paper.

2 Design of Pigpen Management System

The Pigpen Management System collects pigpen environment information and video information through environmental sensors measuring environmental elements and CCTV. It also supports the monitoring and control of pigpen status.

2.1 System Architecture

The proposed pigpen management system is comprised of physical layer, middle layer and application layer. The physical layer is comprised of sensors, CCTV and pigpen facilities as in Figure 1. The middle layer supports the communication between physical layer and application layer. It makes the pigpen information into database and provides with monitoring and control service, maintaining the growth environment of pigs at optimum status. The application layer is comprised of

interfaces which support the pigpen environment monitoring and pigpen facilities control service.

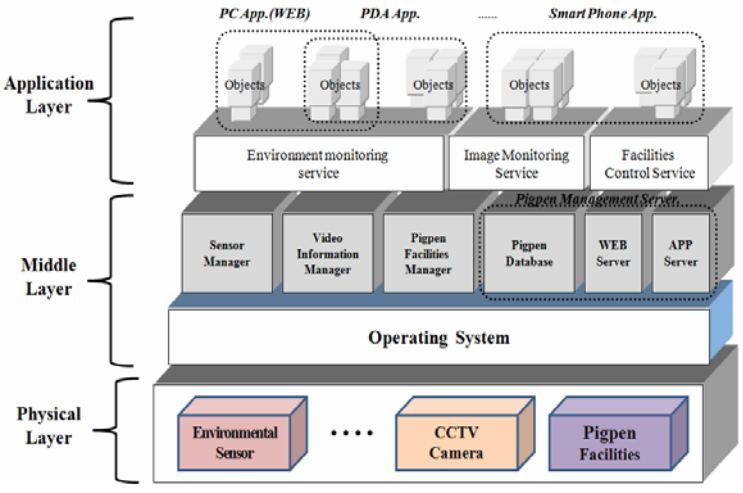

Fig. 1. Pigpen management system architecture

Physical Layer. The physical layer is comprised of environmental sensors, collecting the pigpen environment information, CCTV, collecting the video information of pigpen and pigs, and pigpen facilities, making the optimum growth environment for pigs.

The environmental sensors can be classified into pigpen internal sensors and pigpen external sensors. Internal sensors measure the pigpen internal environmental information such as luminosity, temperature, humidity and CO2. External sensors measure the external environment change of pigpen.

CCTV in the pigpen collects the video information of pigpen and pigs. Pigpen facilities are comprised of lightings, humidifier, air conditioner and ventilator which control the pigpen environment that gives impact on the growth of pigs such as luminosity, temperature, humidity and CO2.

Middle Layer. The middle layer is comprised of sensor manager, video information manager, pigpen facilities manager and pigpen management server. The sensor manager manages he environmental information collected at the sensors in the physical layer. Video information collected at CCTV is managed by video information manager. Pigpen management server, with pigpen database comprised of pigpen information, monitors and controls pigpen facilities.

The sensor manager does 'format processing', which is changing the pigpen environmental information collected at the environmental sensors of physical layer into a format that can be saved in the pigpen database, 'units change', which is changing the units to meet with measurement elements, and 'update query', which is processing the data to save in the pigpen database.

The pigpen facilities manager receives the control signal and operates/manages pigpen facilities. It also saves the pigpen facilities status in the pigpen database. The video information manager provides web with stream data.

The pigpen database saves 'pigpen facilities environment data', collected at the sensors installed inside/outside of pigpen such as luminosity, temperature, humidity and CO2, 'video data', collected at CCTV, 'pigpen facilities status/control data' and 'environmental standard values' for the automatic control and status notification, in the tables allocated to each of them.

The pigpen management server is located between the producer and pigpen database. It examines the environmental data saved in the pigpen database in fixed cycle, reports them to the producer and controls the pigpen facilities by comparing them with the environmental standard values saved in the pigpen facilities control table.

Application Layer. The application layer is comprised of application services supporting various platforms such as laptop, web, PDA and smart phones. It provides producer with 'pigpen environment monitoring service', 'pigpen video monitoring service' and 'pigpen facilities control service'.

2.2 Services of Pigpen Management System

This system provides with 'pigpen environment monitoring service', enabling the observation of internal/external environmental information of pigpen, 'pigpen video monitoring service', providing with pigpen video in real time, 'pigpen facilities control service', enabling the automatic control and manual control of pigpen facilities by producer based on the environmental standard values, and 'danger alarm service', giving notification of dangerous situation at the pigpen.

Pigpen Environment Monitoring Service. The pigpen environment monitoring service shows the pigpen environmental data, collected at the environmental sensors measuring the environmental elements, such as luminosity, temperature, humidity and CO2, to producer through GUI so that producers can identify the environment changes of internal and external of the pigpen.

The detail of this service is that it collects pigpen internal/external environmental information giving impacts to pigs growth such as luminosity, temperature, humidity and CO2 from the environmental sensors installed at inside/outside of pigpen and transmits the information to sensor manager periodically.

The sensor manager will analyze the received data and extract each sensing value. Their formats will be changed and they will be saved in each table of pigpen database. The pigpen management server transmits pigpen internal/external environmental information saved in the pigpen database to producer and the producer can monitor the environmental information of pigpen through this information.

Pigpen Video Monitoring Service. The pigpen video monitoring service provides producer/consumer with video of pigpen/pig-individuals through CCTV installed in the pigpen.

The CCTV sends the pigpen video to video information manager and the video information manager provides with this information by web through Internet. Users can confirm the pigpen video information through Internet.

Pigpen Facilities Control Service. The pigpen facilities control service enables the pigpen management server automatically control the pigpen facilities, or, the producer manually control the pigpen facilities based on the collected information at the CCTV and environmental sensors installed at inside/outside of pigpen.

The automatic control service saves the information collected from pigpen at pigpen database. The pigpen management server calls up the information and compares it with the environmental standard values saved in the pigpen database. If it is more than or short of standard value, it will confirm whether the pigpen facilities are operating as saved in the pigpen database. Then it will send the control signal to pigpen facilities manager and control the pigpen facilities.

When pigpen facilities operate, the pigpen facilities status information is saved in the pigpen database and it will be notified to user.

The manual control service saves the information collected from pigpen in the pigpen database and the pigpen management server sends the information to the user in real time.

If the user wants to control the pigpen at this time, the user will send the pigpen facilities control signal to pigpen management server through GUI. The pigpen management server will check whether the pigpen facilities are operating through pigpen database and send the control signal to pigpen facilities manager to control the pigpen facilities.

Danger Alarm Service. The danger alarm service tells the weather change and pigpen status change to farmers in real time and takes emergency measure to prevent danger in advance. The data sensed at the environmental sensor is sent to the sensor manager. The sensor manager extracts the sensing values from received data and saves them in the pigpen database. The saved sensing values will be periodically monitored by pigpen management server. If it would be more than or less than the standard value, it will be notified to the element where the event had occurred.

3 Implementation of Pigpen Management System

3.1 Components of Pigpen Management System

Environmental Sensors. In order to collect the environmental information of pigpen, WSN environmental sensors were installed at inside/outside of pigpen. These sensors will form the wireless network together with WSN sensor gateway in the pigpen. The sensors are classified into ‘integrated sensor node’, measuring the temperature, humidity and luminosity, and 'CO2 nodes', measuring CO2.

Fig. 2. Integrated sensor node and CO2 sensor

The integrated sensor node receives the sensor data from temperature, humidity sensors. It processes the data at MSP430 MCU and transmits them to relay node and gateway, using CC2420 RF chip. In order to reduce the heat impact the sensor receives from the node, the node and the sensor will maintain certain distance from each other.

MSP430 is 16bit RISC with 48Kbyte 'program memory' and 10Kbyte RAM inside. It can process multiple sensor data at high speed. CC2420 is RF chip supporting Zigbee. It supports the frequency band of 2400~2483.5 MHz. It operates in DDDS method, supports O-QPSK modulation method and 250k bps baud rate. It enables real time wireless communication with small power consumption.

SHT71 was used for temperature/humidity sensors. SHT 71 temperature/humidity sensor has temperature sensor and humidity sensor in one body. It works on relatively small power source of 2.4V~5.5V and has small power consumption of average 28 uA. Having correction memory, it has 14bit A/D converter and digital 2-wire interface. It measures temperature from '-40°' to '120°' with 0.5° error accuracy. Humidity can be measured between 0% and 100% with 3.5% error accuracy.

3.3V operating voltage was connected to integrated sensors node and digital 2-wire was connected to MSP430 circuit to process the temperature and humidity information of pigpen.

CO2 sensor uses NDIR measurement method. It measures the range of 0 to 3,000 ppm with 3% error accuracy. RS485 method was used for communication method.

CCTV. In order to monitor the pigpen by 24 hours video, monitoring camera based on IP was installed as in Figure 3. This camera can monitor the pigpen status in real time and is also used to find out the cause of accident, in case there was an accident such as theft or accident in the pigpen, by monitoring and recording the pigpen inside 24 hours. The recorded video information is transmitted to the 'pigpen management server', where they are saved in the database after classification by pigpen ID and camera number.

Fig. 3. DVR and CCTV camera

Pigpen Facilities and Environmental Control Device. Luminosity, temperature, humidity and CO2 give impacts on the growth of pigs. Figure 4 shows the environmental control devices in the pigpen, which enables the control of pigpen facilities such as lighting, humidifier, fan heater, air conditioner and ventilator for those. Through these environmental control devices, it is possible to maintain pleasant pig-raising environment in the pigpen.

Fig. 4. Environmental control device and Pigpen facilities

Pigpen Management Server. The environment measurement data in stream-form transmitted from pigpen is parsed and saved in the database. At the same time, it is sent to the manager in charge of relevant pigpen so that he/she can know the environment change in real time.

The process of pigpen environmental status of pigpen is classified into two processes. First one is automatically controlling the environmental status from system in reference to the designated environmental standard data. Second is directly controlling the system dependent on the necessity of the manager.

Applications. GUI for manager is developed for web environment. Tomcat-6.0.20 is used for WAS and 'mysql' is used for database. The latest released version 5.0 was used. It was possible to collect the pigpen environmental information and video information of pigpen through sensors and video monitoring camera and constantly monitor/control the pigpen status through user-intuitive GUI by way of above result.

Figure 5 shows the Web GUI of pigpen management system.

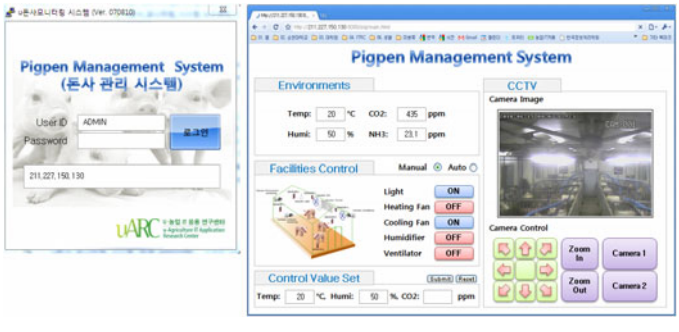

Fig. 5. Web Graphic User Interface of Pigpen Management System

4 Results

4.1 Measurement Environment

In order to complete the design and evaluate the performance of this system, two test-beds were established in two pigsties. Pigpen A had sensors and WSN. Pigpen B had

sensors, WSN and 'pigpen management system'. Both pigpens were located in the same area with 5m distance from each other.

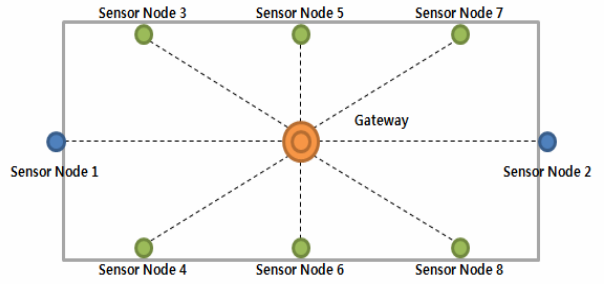

Fig. 6. Wireless sensor networks topology

Figure 6 is the structure of sensors and gateways installed in the two pigpens. Sensor 1 and sensor 2 are located outside of pigpen to measure the external temperature and humidity. Sensors 4 to 6 were installed inside pigpen to measure the internal temperature and humidity.

4.2 Measurement Results and Analysis

The environment sensors installed at pigpen send measured data to server every 10 minutes. The server applies 'the pigpen environment decision making method' to the measured data and control the pigpen environment. Measurement period was from 00:00 hours of April 1st, 2010 until 23:00 hours of April 3rd. The measured environmental data are shown in graph with one hour interval.

Figure 7 is the variations of temperature and humidity in pigpen A using existing control method.

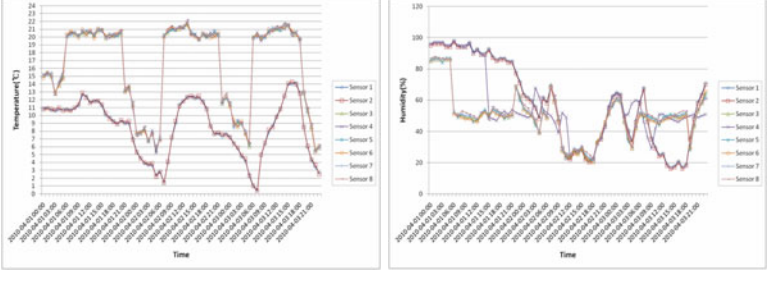

Fig. 7. Variations of temperature and humidity in pigpen A

The measurement result of pigpen A suggests that the temperature and humidity of pigpen inside keep constant level from 06:00 hour to 20:00 hour, because the producer directly controls the pigpen facilities. However, from 20:00 hour to 05:00 hour, there are rapid changes in the temperature and humidity caused by absence of

proper pigpen facilities control. Such rapid environmental change in the pigpen gives severe stress to pigs, which can lead to the deaths of pigs.

Figure 8 is the variations of temperature and humidity in pigpen B which has operating 'pigpen management system'.

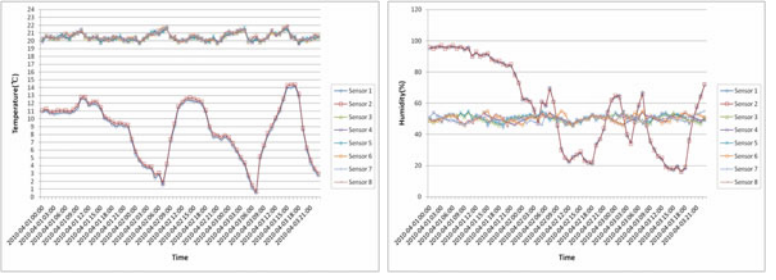

Fig. 8. Variations of temperature and humidity in pigpen B

Pigpen B generates the estimated data based on the measured data by way of 'pigpen management system' proposed by this research. It activates the pigpen internal control devices and it was possible to maintain the pigpen internal temperature and humidity near to the environmental standard values. Pigpen B showed uniform temperature and humidity status compared to pigpen A using existing control method.

This measurement result suggests that the pigpen operation by proposed pigpen management system is more effective than the pigpen operation by existing control method.

5 Conclusions

This research proposed 'Pigpen Management System' using wireless sensor networks as the system to manage the pigpen environment in integrated way in the ubiquitous agricultural environment.

The pigpen management system is comprised of three layers. The roles and services provided by these three layers have been explained. The comprising elements of each layer provide user with organic information by collecting and managing the environmental elements in the pigpen. The system provides with management devices proper to pigpen, saves the provided data, makes a 'control manual' and keeps the record, so that there would not be trial-and-error situation even if the person in-charge would be replaced. It is expected that the mortality rate of pigs could be reduced substantially.

The pigpen management system using wireless sensor networks will contribute in the saving of labor force in the pig-raising farmers, production of high quality pork and further contribute in the securing competitiveness of pig-raising industry, by way of joining pig-raising industry with ubiquitous technology.

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