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Design of Real-Time Monitoring System for Recycling Agricultural Resourcing Based on USN

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ABSTRACT

In this paper, we propose a integrated real-time monitoring system for recycling agriculture resourcing based on USN. We design and implement the monitoring system so that we can integrate the quality control of farmyard and liquid manures, barn environment monitoring, and positioning information control into a total management system performing recycling of excrement and manure. Selection of sensors and sensor-node construction and requirements, structure of wire/wireless communication networks, and design of monitoring program are also presented. As a result of operating our system, we can get over various drawbacks of conventional separated system and promote the proper circulation of excrement up to the farmyard. We confirm that these advanced effects arise from the effective management of the total system integrating quality control of farmyard/liquid manure, barn/farmhouse information, and vehicle moving monitoring information etc. Moreover, this monitoring system is able to exchange real-time information throughout communication networks so that we can construct a convenient information environment for agricultural community by converging IT technology with farm and stockbreeding industries. Finally we present some results of processing using our monitoring system. Sensing data and their graphs are processed in real-time, positioning information on the v-world map offers various moving paths of vehicles, and statistical analysis shows all the procedure from excrement occurrence to recycling and resourcing.

Key words*: Recycling, Real-time Monitoring, Resourcing, USN, Sensor, Network, Excrement, Manure.*

1. INTRODUCTION

In recent years, the major part of excrement from domestic animals is feces and urine generated by cows(44%) and pigs(38.3%). Even though the excrement occupies just 0.9% of total amount of wasted water, its influence on the total water pollution is about 26% on the basis of BOD and 54% on the basis of Nitrogen [1]. The government recognized this serious problem and has been struggling to reduce excrement and recycle it to be liquid manure, which prepared a foundation of regulations for resourcing this excrement of domestic animals. But despite of these government's policies, discarding excrements into the ocean could not be stopped and the recycling system from occurring to resourcing procedures of excrement could not be properly operated.

With these crucial environments of stock raising industry, various applications of radio sensor networks on the area of agricultural recycling have been making ordinary monitoring of the objects and environments to be possible. Moreover, they continuously require that USN(ubiquitous sensor network) technologies should be applied on the actual site of farmland in relation to excrement of domestic animals. Farmyard and liquid manures are especially treated to be recycled using these summit USN technologies.

According to some recent studies, new IT convergence could be defined as connection, integration, and making fusion with other conventional industries that can be generated as a new kinds of industries creating chances of novel businesses [2]. This concept of IT convergence has correctly been applied to our focus on agricultural recycling system converged with USN monitoring technologies. However conventional studies used to separate monitoring system into one for barn environment, the other one for quality of liquid manure, and one using positioning information, etc. This separated approach reveals a serious limitation in the real livestock farming environment. For example, we can more effectively treat against a contagious disease of domestic animals if the monitoring system supplies an integrated information including

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barn environment, quality of manure, and positioning information of excrement moving etc. It has been difficult to manage such a serious and urgent situation using this separated information we could obtain from the conventional methods [3], [4].

In this paper, we propose a structure of real-time monitoring system for recycling agriculture based on USN. In addition we design and implement the proposed system so that we can integrate the quality control of farmyard and liquid manures with the total recycling procedure of excrement including positioning mechanisms. In order to describe our dedications, we present USN technologies and radio communications as the basic IT necessary for our monitoring system, and practical aspects of recycling agriculture concepts as our objective application area in Section 2. We give an account of the structure of proposed system and describe its design and implementation principles including H/W and S/W in Section 3. Some concepts of message treatments, management of registration information, and statistical analysis are also included. Finally in Section 4, we arrange the results of this study and offer some tips for the future works.

2. BRIEF REVIEW OF RELATED TECHNOLOGIES

2.1 Ubiquitous Sensor Network

USN is a kind of information network widely used in a ubiquitous environment. We receive signals from tag or sensor attached on the target object to obtain information about the object itself and environments so that we can recognize, store, revise, and integrate them to be used for other automation schemes.

Fig. 1 shows the basic concept of USN. It basically offers various information related to a variety of sensing targets in order to connect communication, broadcasting, and internet to the integrated wideband multimedia service which constructs the basement of wire/wireless centralized network infra structure [5], [6].

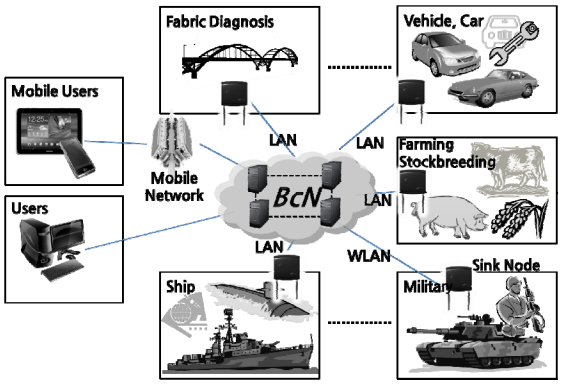

Fig. 1. Concept of USN

As shown in Fig. 2, USN consists of a sensor field, base node, and outer network like BcN or Internet. Sensor field contains a lot of sensor nodes in which a sensor, a processor, and other peripherals included. Base node(or sink) connects the sensor field with outer network and it deliver the obtained environment information by any sensor node to the target managing user node

The necessary characteristics of a sensor node are computation capability, sensing mechanism, wireless communication skill as well as low power and effective resource management etc.

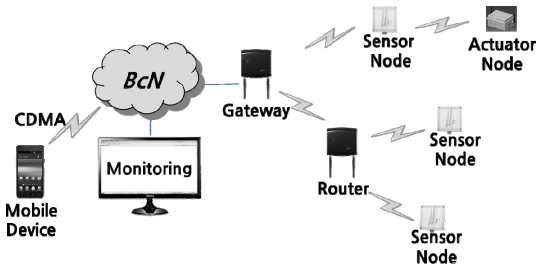

Fig. 2. Structure of USN

In this monitoring s ystem, we use these concepts of USN as a sensing data collecting scheme, positioning scheme, and monitoring program in connection with GPS module.

2.2 Wireless Communication Technology

Communication technology mainly used for remote control scheme can be divided into 2 parts. One is based on wire communication, and the other one is on wireless. Wire scheme is connected using optical fiber, coaxial cable, twisted pair and/or PLC etc. On the other hand, wireless communication can be divided into WLAN and WPAN. Moreover WLAN consists of 2 kinds of systems using 2.4GHz and 5GHz bands. And there are also 2 kinds of WPANs that can be divided into high-speed type using UWB and low-speed type using Zigbee or Bluetooth [7]. Table 1 shows some remote control schemes and their comparisons by using wireless communication technologies.

Table 1. Remote Controls Using Wireless Scheme

Schemes	Freq.Band	Rate (bps)	Distance (m)	Apps
WLAN	2.4/5GHz	54/600M	50~100	Internet
UBM	3.1~10.6GHz	200/480M	10	HD A/V
LowUWB	3.1~10.6GHz	1M	50	Control/ Positioning
Bluetooth	2.4GHz	1M	10	Speech
Zigbee	868/915MHz 2.4GHz	20/80/250 K	30/100	Remote Control
RFID	125k/12.56M/ 400M/900MHz	30K	5	Logistics/ Management

When sensor data are collected, we need low power characteristics, long lifetime, and rational distance coverage in the controller even though the amount of data delivered simultaneously is comparatively small. For our target monitoring system, we use 2.4GHz Zigbee scheme in order to satisfy these requirements. International standard Zigbee Alliance consumes the lowest electric power among all the IEEE wireless schemes. It based on IEEE 802.15.4 which intends low-speed, local distance, and low cost. Because its structure of protocol is simple, we can easily approach to set up this scheme [4], [7].

Fig. 3 shows the structure of IEEE 802.15.4. It basically offers multipath links in order to prove stability and security of communication interface by the process of automatic linking to another path when the operating link possibly breaks. On the other hand, Zigbee NWK(network layer) makes MAC Layer operated properly and offers an interface to the Application Layer as shown in Fig.4. It supports Star, Tree, and Mesh topologies and it controls routing and security proof. Application Layer is a performing environment through which application objectives can exchange data with each other. According to the definition from Zigbee standard, application objectives are located on the top of Application Layer and defined by the manufacturer.

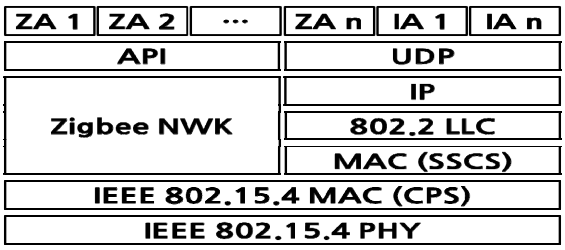

Fig. 3. Structure of IEEE 802.15.4

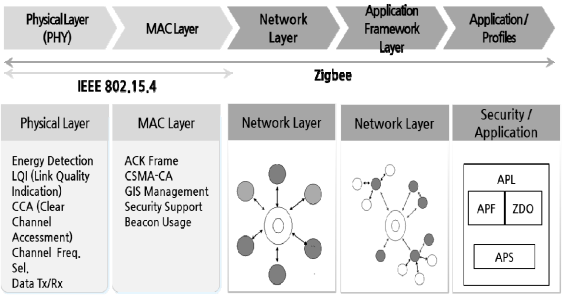

Fig. 4. Hierarchical Structure of Zigbee

What we are applying to our focused monitoring system are CSMA(carrier sense multiple access) the collision avoiding algorithm among the main part of Zigbee technology. This algorithm is based on DSSS(direct sequence spread spectrum) scheme which spread digital signals on the wide frequency band to transmit simultaneously so that we can obtain an excellent noise immunity and good security throughout wireless communication processes [8]-[10].

2.3 Some Aspects of Recycling Agriculture

The concepts of recycling agriculture in a broad sense and a narrow sense are depicted in Fig. 5. Generally speaking, in the beginning plants would be foods of animals and supply nutritive substance needed on growing animals, the excessive nutriment would be excreted as feces and urine. And these excrements are decomposed by the soil microbes to be another type of nutriment for plants. This process draws a perfect closed loop of continuous circular recycling.

Natural recycling agriculture can be defined as a farming through healthy growing plants and domestic animals using the principle of material circulation of the natural ecosystem [11]. On the other hand as a narrow sense of meaning, it defines an agricultural strategy that improves productivity of farming by recycling excrement of domestic animals to be manures for the soil nutriment.

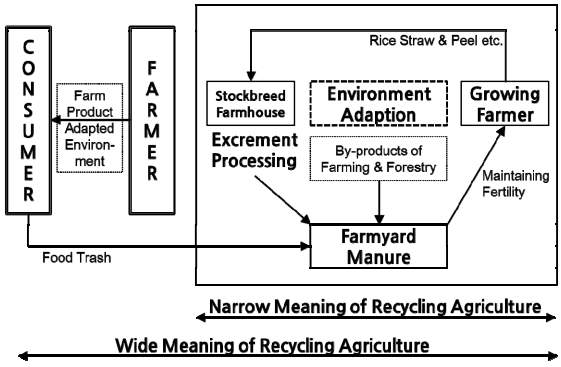

Fig. 5. Fundamental Concept of Recycling Agriculture

In recent years, excrement is reused by various method such as resourcing farmyard or liquid manure, purified discharge, and energy content. Especially, in the process of resourcing we should get correct statistics of amount of occurrence, facilities, and farmland referred so that we can derive some core management factors. We can obtain Table 2 which indicates some important management factors and their criteria following the steps from occurring to recycling.

Table 2. Typical Handling Steps for Excrement

Steps	Criteria	Managing factors
Occurrence	How much?	Growing amount each
Inflow/Moving	How is it moving?	Car moving information
Processing	How is it processed?	Facilities and capabilities
Recycling	Where is it recycled?	Manure usage for land

According to the government announcement, facilities of excrement resourcing will be increased up to 150(Ea) by 2017 and they can process about 4.5 million tons of excrement. So we can sufficiently think about the importance of monitoring system for the analysis of real-time occurrence of information.

3. DESIGN AND IMPLEMENTATION OF THE MONITORING SYSTEM

3.1 Structure of the System

We present the structure of proposed system as show in Fig. 6. The system consists of facilities collecting sensor data, equipment for positioning information, and a supportive monitoring program. Their design concepts and connectivity are as follows;

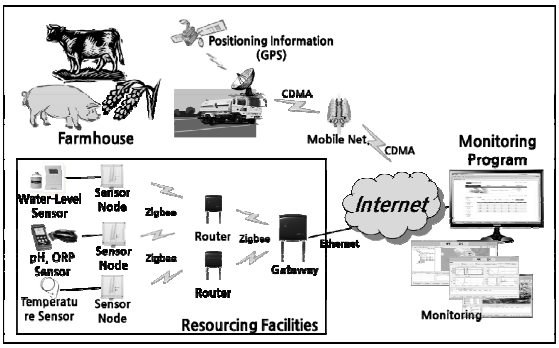

Fig. 6. Block Diagram of the Monitoring System

Facilities collecting sensor data can be divided into 3 parts as follows; The 1st part is a sensor node which collects data from sensors and transmits them to a junction node immediately. The 2nd part is a junction node which delivers the sensor data to the collecting devices, and finally the 3rd party is a collecting node which delivers the transmitted sensor data to the monitoring program. Equipment for positioning information can be divided into a GPS module which collects positioning information and a CDMA module which delivers this collected information to the monitoring program. If sensor data and positioning information are entered from these 2 parties, the monitoring program will be operating to real-time manage the collected sensor data, the positioning information for dealing with excrement processing aspects, and the basic information about users so that we can be monitoring real-time for the purpose of recycling agriculture resourcing procedure.

3.2 Design of the System Hardware

3.2.1 Sensors Used

One of the most important elements that actually make it possible to operate our monitoring system is the sensor. Therefore we should be careful to select the sensor during the design process. We finally chose pH, ORP(oxidation reduction potential), Temperature, and Water-Level sensors to implement our monitoring system.

The process of making farmyard or liquid manures from excrements of domestic animals mainly depends on the metabolism of microbes so that temperature data play a major role in the effectiveness of the process, which can be measured using Temperature sensors. On the other hand, pH sensors detect the loss of Nitrogen. In the case of manure production process, the higher pH value detected, the more Ammonia evaporation occurred to be loss of Nitrogen happening air pollution and lack of plants' absorption [12].

ORP sensors are widely used to evaluate dissolved oxygen in wasted water, organic substrate, activity of organism, toxic compound, sludge digestion, biological nutrient removal, as well as chemical oxidation and reduction process etc [13]. Therefore we apply Temperature, pH, ORP sensors to our monitoring system so that we can properly manage the quality of farmyard and liquid manures. In addition, we apply Water-Level sensors to manage input amount of excrements and output amount of liquid manures installing in the collecting water tank and the storage tank. Various positions of sensor nodes are depicted in Fig. 6.

3.2.2 Design of System Hardware

Zigbee network designed in the system consists of Sensor node(end device), Junction node(router device), and Collecting node(PAN coordinator).

First of all, Sensor node is a kind of input end detecting perceived data and controlling devices. This node is located at the end of network so that it can only collect data but cannot be related to handover other wireless packets or devices. Junction node is a kind of router device delivering wireless packets from other devices to adjacent router devices or Collecting node(PAN coordinator). Finally Collecting node controls the total Zigbee network and converts the Zigbee packets collected from wireless links to the Ethernet packets to be used on a wire communication network. Then the packets are delivered to the monitoring program. On the contrary, the Ethernet packets generated by the monitoring program should be converted to Zigbee packets to be transferred to the target devices through the Collecting node.

We present the essential requirements of Sensor node including Temperature, pH, ORP, and Water-Level sensors in Table 3. Moreover the process of detecting data and delivering them to Collecting node throughout RF module or Zigbee communication is depicted in Fig. 7.

Table 3. Requirements of Sensor node

Items	Requirements
Power source	AC220V, SMPS(DC12V, 5V)
MCU	ATmega128L
Wireless Comm	Zigbee (250Kbps/SPI Comm.)
USB to Serial	CP2102
Interface	Power ON/OFF SW App application button/Reset button Applied LED, USB to Serial Port Relay Output Port

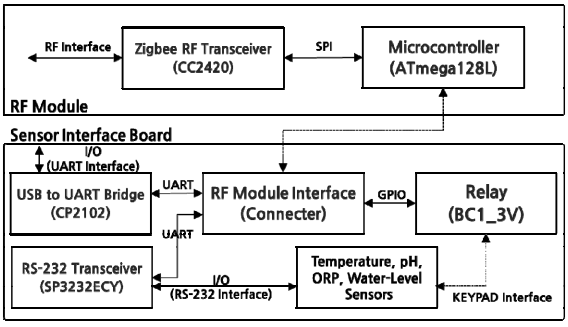

Fig. 7. Block Diagram of Sensor node

Electric power for Sensor node is supplied by AC220V and constructed to be divided following the sensor requirements. The inner part of power supply has SMPS(DC12V/5V). We construct RF module for wireless communication which can changed the method of linkage according to the environments or other applications. In addition we install On/Off SW, App application button, Reset button, and Applied LED to be controlled easily by the user at a real site.

The requirements of Collecting node which delivers data collected from Sensor node or Junction node to Ethernet

throughout Zigbee wireless communication are given in Table 4. And its block diagram is given in Fig. 8.

Table 4. Requirements of Collecting node

Items	Requirements
Power source	AC220V, SMPS(DC5V)
MCU	ATmega128L
Wireless Comm	Zigbee(250Kbps/SPI Comm.)
Wire Comm	10 Base T/100 Base TX Ethernet TCP/IP Protocol Support
USB to Serial	CP2102
Interface	Power ON/OFF SW App application button/Reset button Applied LED, USB to Serial Port 10/100 Ethernet Port

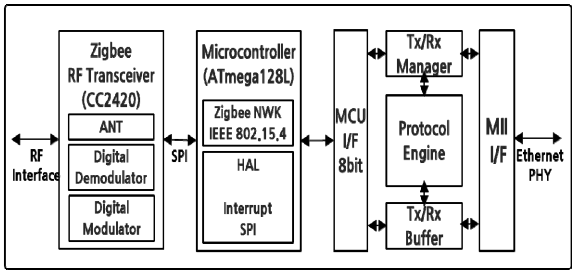

Fig. 8. Block Diagram of Collecting node

ATmega128L is used for MCU to control RF, Ethernet Tranceiver and to perform process of packet conversions. Wireless communication supports Zigbee with 2.4GHz which has 250Kbps transmission rate. On the other hand, wire communication supports Ethernet TCP/IP protocol. Electric power for Collecting node is supplied by AC220V and inner part of power supply has SMPS(DC5V). In addition we install On/Off SW, App application button, Reset button, and Applied LED from outer side of interface and construct an USB to serial port so that we can confirm the inner operations of Colleting node, which should be controlled easily by the user at a real site.

3.3 Design of the System Software

Main role of Monitoring program is displaying the collected data and saving them into database. Monitoring program constitutes a core of system software of the total monitoring system.

Fig. 9 shows a block diagram of the system software. It consists of message processing function and management function. In detail, message processing function performs the processing of sensor data collected by Sensor node and delivered through Zigbee wireless communication and positioning delivered from GPS through CDMA wireless communication. Management function performs the processing of registration, excrement, and statistical or analytical measure.

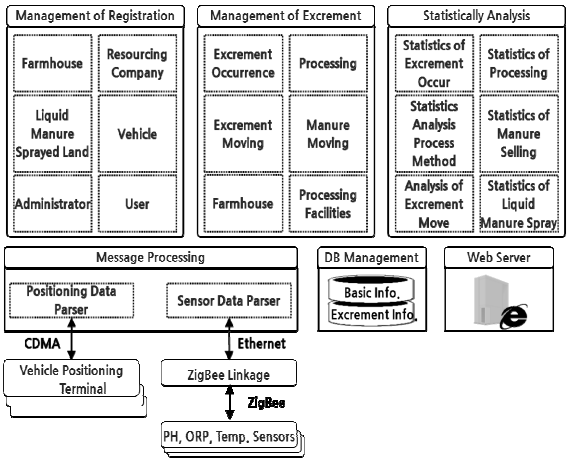

Fig. 9. Structure of the System Software

System software conducts the role of operation for controlling hardware described above. It totally consists of managements for 'Registration', 'Excrement' and 'Statistical Analysis'. Registration includes farmhouse, resourcing company, land sprayed by liquid manure, vehicle, and administrator/user with their essential items. Excrement management deals with its occurrence, processing, moving, and farming houses for their processing facilities. On the other hand, Statistical Analysis handles various statistics about excrement, processing, manure, and their processing, moving, and spray etc. For the sake of these works, we need a message processing scheme with CDMA, Ethernet, and Zigbee linkages. In addition we construct a management DB and Web server to make system to be perfect operation and their communications.

3.3.1 Message Processing Experiment

We present an example of real-time processing to be a table and a graph as shown in Fig. 10. Message processing function of the Monitoring program collects the sensor data from sensors installed in facilities for farmyard or liquid manures and we can confirm the real-time aspects of excrement heaping throughout the tables and graphs.

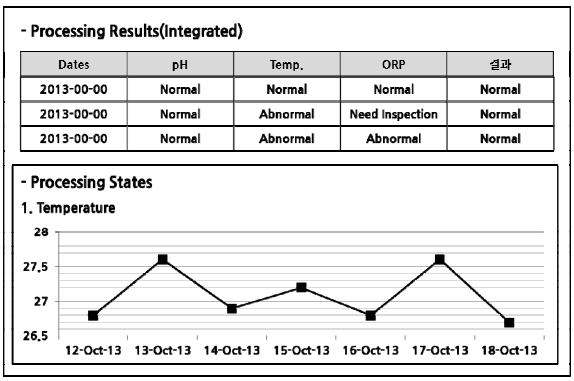

Fig. 10. An Experimental Result of Message Processing

Moreover Monitoring program provides moving and recycling information of excrements and/or manures. We construct a database of collecting data of excrement of domestic animals and dusting information of liquid manure in

the process of moving and circulation. Fig. 11 shows an example of message processing using positioning information.

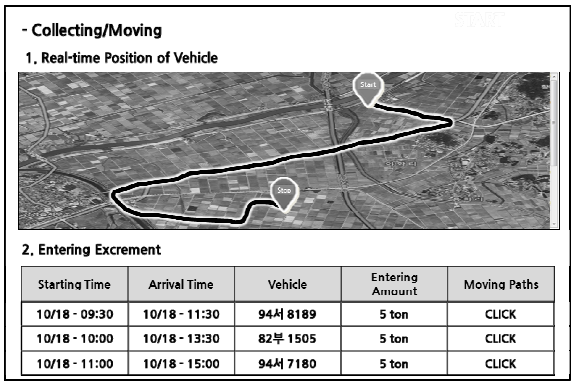

Fig. 11. An Example of Positioning Information Usage

We present real-time vehicle positioning information and the moving paths by comparing the current position with positioning information stored in DB. These vehicle positioning and moving/recycling information are realized in Monitoring program using 'V world' the integrated on-line map service offered by the Ministry of National Land and Ocean of Korea government [14].

3.3.2 Management of Registration Information

Register part of Monitoring program performs function of managing information registered on the system and integration of related registrations. Fig. 12 shows an example of registration information tables which related to any farmland, company, and vehicle.

A registration of farmhouse that generates excrement consists of breeding information of corresponding farmyard, farmer information, address (including GPS coordinates), and other contact point. These are core manageable elements at the step of generation of excrements. For a company of excrement resourcing can be registered and managed by processing facilities, capabilities, and their basic information of the company. Registrations of the farmyard being sprayed by liquid manures include basic information of that farmyard, analysis of soil, prescription of manure, and their amount of spray. Finally vehicle registration consists of basic information of the car and type of service including collection of excrement, spray of liquid manure, movement of liquid manure, and amount of proper loading etc.

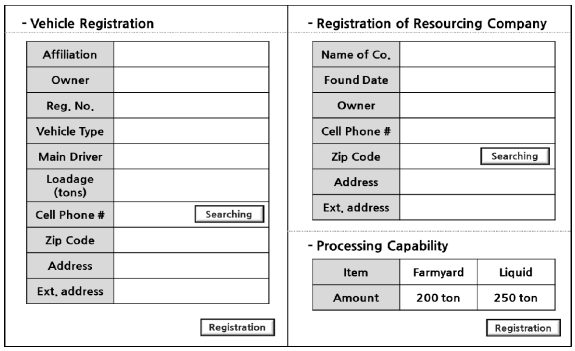

Fig. 12. Examples of Registration and Management Tables

When a user is entering his/her membership, Monitoring program divides them into farmhouse, company, and provincial government as shown in Fig. 13.

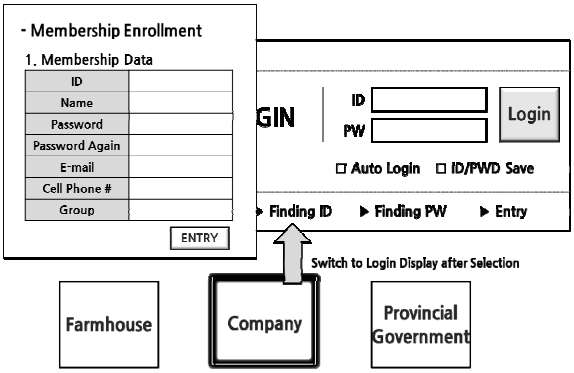

Fig. 13. Management of Registration Information

This strategy makes it easy to manage all users separated into general users and administrators. In addition program gives each user specified access authorization according to their roles in the system including its password check mechanism and hierarchical right assignments.

3.3.3 Management of Excrement and Statistical Analysis

The essential management entries of excrement circulation are occurrence of excrement, processing, moving of excrement, moving of farmyard/liquid manure, farmhouse, and processing facilities etc. On the other hand, statistical analysis mainly concludes statistics of excrement generation measured by kinds of domestic animals and/or by farmhouse, statistics of processing by kinds of companies, and statistics of spray of liquid manure etc. Monitoring program totally performs these functions. We present a result of statistical analysis in Fig.14. Monitoring program detects the levels of collecting tanks and processes and analyzes, of which are displayed like types of rod graphs as show in Fig. 14.

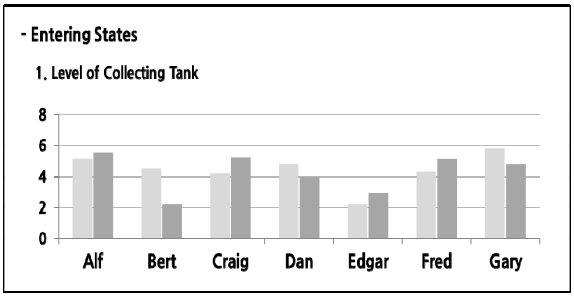

Fig. 14. An Example of Statistical Analysis

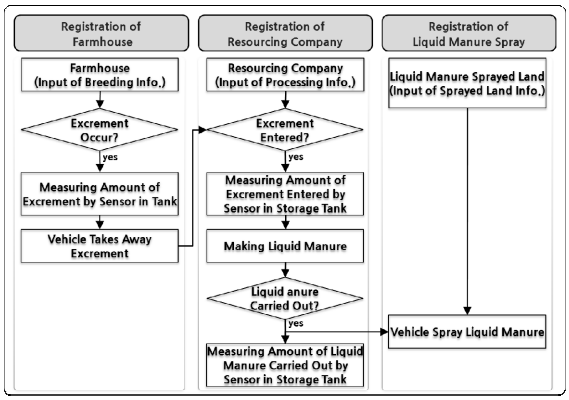

Fig. 15. Data Flow Chart of Excrement Processing

Fig. 15 shows a flow chart of excrement processing which indicates the data flow from occurrence of excrement, processing by companies to recycling and circulated resourcing. Excrement processing consists of confirming excrement collection based on moving information of vehicles, confirming excrement entry using the sensors installed in the tanks, and acceptance procedure to be farmyard/liquid manures. After finishing these processing, if a requirement of spraying liquid manure occurs, monitor measures the amount of output manure using the sensors installed in storage tank. The information of spraying liquid manure on the farmyard should be detected by vehicle moving information.

4. CONCLUSION AND FUTURE WORKS

We have designed and implemented a real-time monitoring system which can manage quality of farmyard/liquid manure and their circular procedures related to the recycling agricultural resourcing in an integrated manner throughout this paper. This system got over various drawbacks of conventional system separated into barn environment, quality of manure, and positioning information so that we can promote the proper circulation of excrement up to the farmyard. These effects arise from effective management of the total system integrating quality control of farmyard/liquid manure, barn/farmhouse information, and vehicle moving monitoring information etc. Moreover, this monitoring system is able to exchange real-time information throughout communication networks so that we can construct a convenient information environment for agricultural community by converging IT technology with farm and stockbreeding industries.

Although the system proposed in this paper generated a kind of new value obtained from the convergence of IT with other industrial area, we could suffer from some limitations of this system as follows; First of all, it is difficult to decide what actions occur in the real operations by the information from GPS only. We need to make for the weak points in the decision procedure supporting additional sources of information. In addition, system performance view points, structure of network for collecting sensor data should be different following the site environment. Therefore we need to construct a testbed to perform an integrated investigation for the site application capabilities of this system, which can be shown as future works.

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