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REMOTE SENSOR NETWORKS FOR PROTECTED CHRYSANTHEMUM PRODUCTION

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ABSTRACT Chrysanthemum is a popular flower in Korea and Japan especially at funerals. Most chrysanthemums are cultivated in indoor facilities. The micro climate such as temperature, humidity, light, water, and nutrient are critical for yield and quality of chrysanthemum. Hence farmers must be present on the chrysanthemum facility to monitor and control growing conditions. To solve these problems and relieve the labour, remote sensor network for monitoring these environmental and operational factors would be a preferable option. In this research, a remote sensor network for protected chrysanthemum production was designed so that farmers could monitor the environmental factors at a distance. Important environmental and operational factors were selected and monitored through wireless sensor network (ZigBee & CDMA). Those factors were provided as control settings for the control of remote systems.

Keywords: Chrysanthemum, environmental monitor, remote sensor networks.

INTRODUCTION An environmental control system is the key factor of crop growth and production for nowadays indoor facility agriculture in Korea. According to Korea government's support in facility gardening, the establishment area of the modernization greenhouse is increasing and the management size of greenhouse is magnified. In order to reduce the cost of production, the environmental control and automation establishment of cultivation management facility are essential. Chrysanthemum which formed the mainstream of flower cultivation is one of the popular flowers in Korea, Japan and Asia especially in funeral. Most chrysanthemums are cultivated in indoor facility (greenhouse). The environmental factors are critical for affecting yield and quality of chrysanthemum. Hence farmers need to stay around the chrysanthemum facility to monitor and control of these factors. To solve these problems and relieve the labour, it is necessary to develop a remote monitoring system capable of analyze and process the real-time data of chrysanthemum facility environment such as temperature, relative humidity, light, nutrient and soil moisture content in order to provide information to a facility control system.

At present, the communication way of system for environment monitor is following. The RS485 bus, CAN bus or Ethernet technology belongs to the wire communication. And Bluetooth and ZigBee technology are short-range wireless communication. The last, remote wireless communication based on GPRS (General packet radio service), GSM (Global System for Mobile Communications). In the case of wire communications, lines related the sensor, signal and power were complicated within the facility environment. According to the poor agricultural environment, the cables were aging and system reliability was getting lower. Also installation and maintenance of the wire communication system were difficult. The existing monitoring system has many disadvantages such as high cost, labour intensity, large power consumption etc. However wireless communications based on GPRS and GSM has obvious advantages in many aspects, especially this technique can give a freedom of moving to the farmer just bring a CDMA cell phone and monitor the facility environmental factor then control the facility control system based on the information from wireless sensor network system. In view of above analysis, a technical solution of remote monitoring system based on ZigBee and CDMA (the mobile phone standards which are often referred to as simply "CDMA") technology for agricultural information was presented.

The environmental information of chrysanthemum facility such as temperature, relative humidity, illumination, nutrient and soil moisture content were monitored. The researchers have found out the location of the room temperature sensor which leads the most effective location of the optimum control system (Lee et al., 1999). Park et al., (2000) researched the soil moisture of the different crops, especially the soil moisture condition affects in water content and quality of the facility cultivation melon. Kim et al., (2000) measured a soil water content and quality to find out the effect of soil water content for tomato production.

Recently, there are many researches to enable future ubiquitous environments based on ubiquitous sensor networks (USNs). In USNs, various sensing devices deployed in wireless sensor networks collect meaningful data from physical environments and the data are delivered to neighbor node through radio interfaces for further processing.

In this paper, a remote monitoring system for protected chrysanthemum production was designed so that producer could monitor environmental information and confirm the results from the remote place. The system will not only solve the problem of farmer, but also have the characteristic of wireless communication, low-cost system. Results of this work would be useful for construction and utilization of the final remote control system.

MATERIAL AND METHODS To build a remote monitoring system of the chrysanthemum facility first, important environmental and operational factors were selected and control ranges of these variables were determined. Then, control modules of the selected variables were constructed and the performances were evaluated.

In this system, the wireless communication senor module consists of two important components. The senor module which consists of the ZigBee module and sensor collects the agricultural information at the site. The sensor module accepts and processes information from sensors based on the ZigBee technology. The remote server stores and manages information from the sensor module based on CDMA technology. So the farmer on remote spot can monitor the environmental information through the cell phone and make a decision about the control factor so that the information sent to the remote server on the relevant port which is control system. Thus the distributed data about agricultural environment will be collected and managed remotely.

The indoor facility experiment was performed in greenhouse size of 70 x 7 m^2 which is located at the YeSan chrysanthemum research institute in Korea. Figure 1 show the chrysanthemums in greenhouse and installed wireless sensor network. This greenhouse has aeration roller on both sides operated by motor and the ventilator on the ceiling.

Figure 1. Chrysanthemum in greenhouse and installed wireless sensor network unit

The Z-Field module was used as wireless sensor network unit and the specification was shown in table 1. As you can see in the table the Z-Field module can communicate in various way which is depend on communication range: short-range wireless communication based on ZigBee, Long-distance wireless communication based on CDMA. The number of sensing channel include temperature, relative humidity, illumination, moisture content, soil temperature and tensiometer, was 5 but it can be applied up to 8 sensors.

Table 1. Specifications of wireless sensing unit (Z-Field system)

Item	**Z-Field sensing unit**
Spec.	Short-range wireless communication : ZigBee Long-distance wireless communication : CDMA-CDMA Wireless communication : Short-range(ZigBee) or Long-range(CDMA)
Power	Battery AA 1.5V x 3 or Adaptor
Extension	Between ZigBee - ZigBee (Router: increase communication distance)
Model	ZFxR-CDMA
Shape	USB cable: wire data logger, short-range ZigBee wireless communication or long-distance CDMA, LCD display
Channel	Temperature, relative humidity, light intensity, moisture content, soil temperature, tensiometer. Total 8channel

The key technology of Z-field sensing module is wireless sensor network using CDMA and ZigBee technology. The function of ZigBee module is set suitably to construct a wireless sensor networks among the modules and several sensor nodes. Thus the distributed data about agricultural environment will be collected and managed remotely. The diagram of wireless sensor network was shown in figure 2.

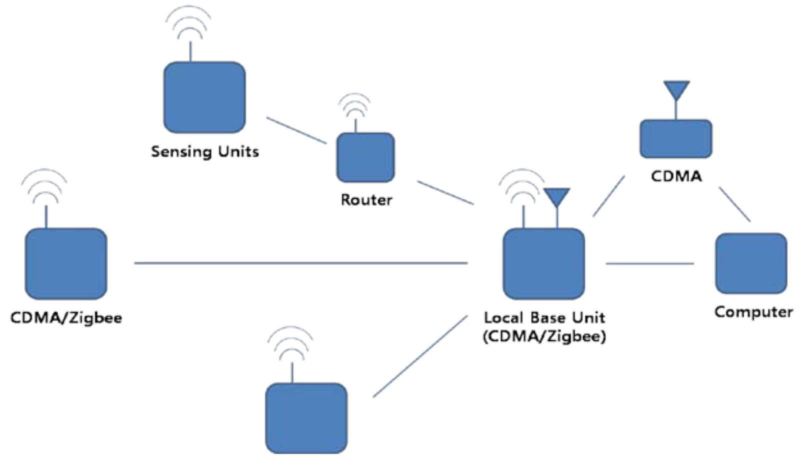


Figure 2. Diagram of wireless sensor network

Z-Field wireless network module has five factors which are temperature, humidity, illumination, soil temperature and soil water content were used for monitoring greenhouse. And the number of sensors was 5 (shown in figure 3).

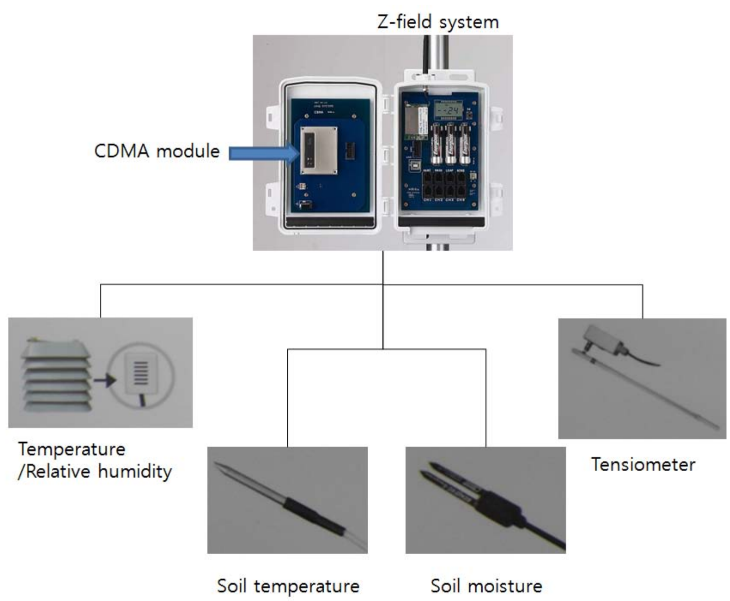


Figure 3. Z-Field wireless sensor network module and sensors

This unit as referred previous the network system can apply on both way short distance/long distance and the setting of the unit such as data logging interval, channel can be adjusted by remote control. The long distance radio communication uses Code Division Multiple Access (CDMA). It means that the wireless sensor unit can be used as a monitoring tool for the environment of the greenhouse within nationwide cellular phone serviceable area. So the environmental information of the greenhouse can be transmitted and saved in the computer and cellular phone located in the laboratory far from the greenhouse (distance between laboratory and greenhouse is about 98 km).

Wireless sensor Temperature, humidity, soil temperature, soil water content and illumination were introduced as followings. In order to record the temperature which is necessary to the chrysanthemum cultivation HA-TH100 were used and the humidity was recorded at the same time. The sensor was installed at the center of the green house. For soil temperature, the ground temperature sensor (HA-T200) laid in underground depth 10 cm. Tensiometer (HA-3021) was used in the experiment for measuring soil moisture contents. The tensiometer measure the surface tension and interfacial tension of a liquid and the data was simply converted into pressure kPa and pF value. Figure 4 show the tensiometer installed in greenhouse among the chrysanthemums and the specification of the tensiometer was displayed in table 2.

Figure 4. Tensiometer installed in greenhouse (laying depth 20 cm)

Table 2. Specification of tensiometer

Item	**Specification**
Sensing area	DIK3160-11/DIK3160-13
Tensiometer cup	ϕ18 mm 90 mm
Size	ϕ18 mm (Laying depth +12 cm)
Pressure range	0 ~ -100 kpa
Input channel	1 channel
Measurement range	±50.00 mV /±500.0 mV /±5.00 V /±50.00 V
Accuracy	±0.5% reading
Logging interval	1/2/5/10/15/20/30 sec, 1/2/5/10/15/20/30/60 min.

In addition to tensiometer, the EC-5 (Model: HA-M05 Decagon Pullman. WA. USA) obtains volumetric water content by measuring the dielectric constant of the media through the utilization of capacitance/frequency domain technology. In the field, the robust design of the EC-5 allows the sensor to be pushed directly into undisturbed soil. However, the compact design of the EC-5 makes it possible to measure volumetric water content in labs and greenhouses. EC-5 moisture sensor specification was shown in table 3.

Table 3. ECH$_2$O EC-5 moisture sensor specification

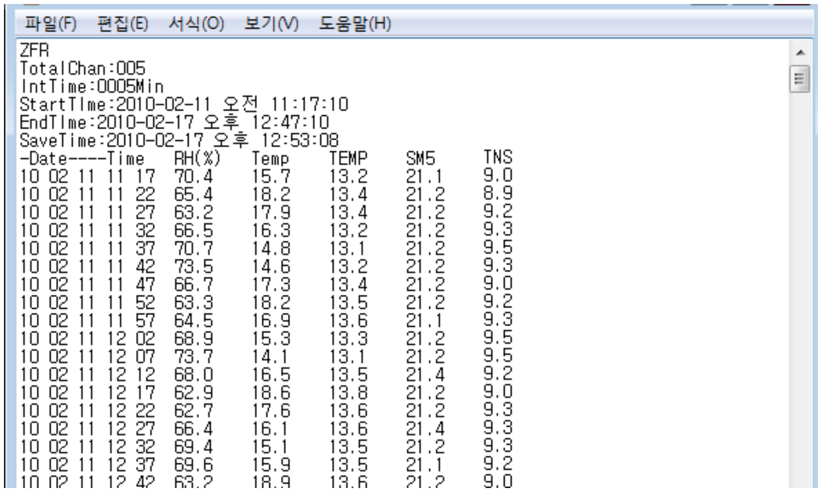
Item	Specification
Sensing range	0~100% VWC
Sensing type	VWC(Volumetric Water Content)
Accuracy	Mineral Soil:
	±3% VWC, All mineral soils
	±1-2% VWC soil specific calibration, up to 8 dS/m
	0.1% VWC (mineral soil)
Resolution	0.25% VWC (rockwool)
Temperature	-40℃to 50℃, 0-100% RH
Power	2.5 - 3.6 V @ 10 mA. Output proportional to input voltage.

For illumination monitoring the web camera (mCam100 Advance Set) was used. Specification of web camera for illumination monitoring was shown in table 4. The camera was connected into the computer by USB cable. And captured image of greenhouse was sent to the cellular phone via image services.

Table 4. Specification of web camera for illumination monitoring.

Model	MCAM 100 Plus
Image sensor	CMOS Type
Resolution	318,176 Pixel
Focal length	30 mm ~ ∞
Frame per sec.	CIF 30 fps, VGA 30 fps
Exposure and white balance	Auto
Interface	USB ver1.1
Motor	Step motor x 2
Horizontal angle	312°
Vertical angle	80° (with view angle)
Cable length	2.9 m
Size and weight	96.9(W) x 86.5(H) x 111(L) (mm), Weight: 350 g
Power	USB DC 5V (±1%) USB, 300 mmA/MAX

CONCLUSION The data acquired from Z-Field wireless sensor network at every 5 min. through the CDMA were displayed in figure 5. The data show total channel, data acquisition interval, start time, end time and save time at the beginning and next the Date, Time, RH(relative humidity), temp(temperature), TEMP(soil temperature), SM5(soil moisture content) and TNS(tensiometer) were recorded as sequential.



파일(F) 편집(E) 서식(O) 보기(V) 도움말(H)

ZFR
TotalChan:005
IntTime:0005Min
StartTIme:2010-02-11 오전 11:17:10
EndTIme:2010-02-17 오후 12:47:10
SaveTime:2010-02-17 오후 12:53:08

-Date----Time	RH(%)	Temp	TEMP	SM5	TNS
10 02 11 11 17	70.4	15.7	13.2	21.1	9.0
10 02 11 11 22	65.4	18.2	13.4	21.2	8.9
10 02 11 11 27	63.2	17.9	13.4	21.2	9.2
10 02 11 11 32	66.5	16.3	13.2	21.2	9.3
10 02 11 11 37	70.7	14.8	13.1	21.2	9.5
10 02 11 11 42	73.5	14.6	13.2	21.2	9.3
10 02 11 11 47	66.7	17.3	13.4	21.2	9.0
10 02 11 11 52	63.3	18.2	13.5	21.2	9.2
10 02 11 11 57	64.5	16.9	13.6	21.1	9.3
10 02 11 12 02	68.9	15.3	13.3	21.2	9.5
10 02 11 12 07	73.7	14.1	13.1	21.2	9.5
10 02 11 12 12	68.0	16.5	13.5	21.4	9.2
10 02 11 12 17	62.9	18.6	13.8	21.2	9.0
10 02 11 12 22	62.7	17.6	13.6	21.2	9.3
10 02 11 12 27	66.4	16.1	13.6	21.4	9.3
10 02 11 12 32	69.4	15.1	13.5	21.2	9.3
10 02 11 12 37	69.6	15.9	13.5	21.1	9.2
10 02 11 12 42	63.2	18.9	13.6	21.2	9.0

Figure 5. Data acquired from Z-Field wireless sensor network at every 5 min.

From figure 6 to figure 9 the temperature, relative humidity, soil temperature, and soil moisture content measured in greenhouse for 1 day at every 5 min were displayed respectively.

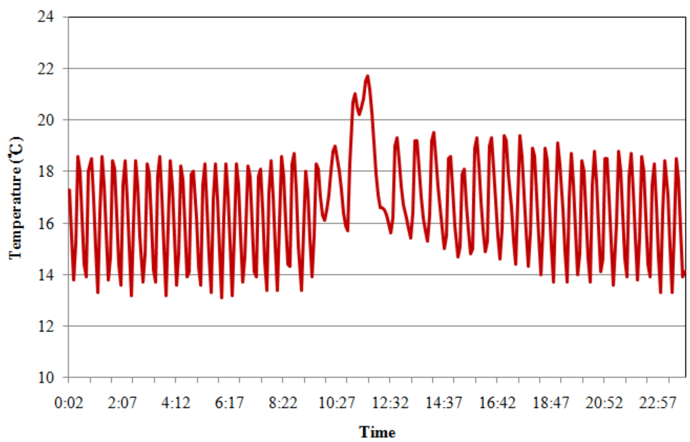


Figure 6. Temperature in greenhouse for 1 day at every 5 min

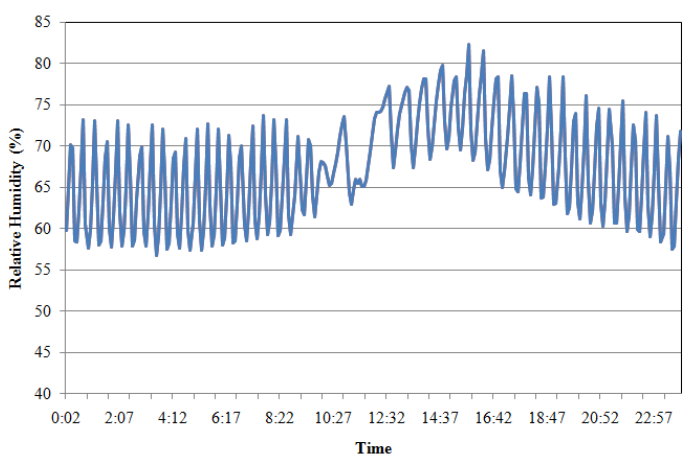


Figure 7. Relative humidity in greenhouse for 1 day at every 5 min

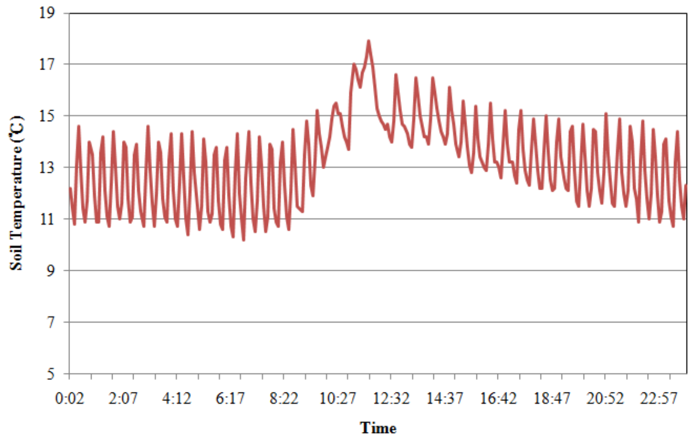


Figure 8. Soil temperature in greenhouse for 1 day at every 5 min

Watering was applied 2 times every day in the morning 9:00 and in the afternoon 2:00 for 1 minute respectively. Irrigation method was drip irrigation and the amount of irrigation was different according to season (spring, autumn 15 L/m^2, summer 20 L/m^2 and winter 10 L/m^2).

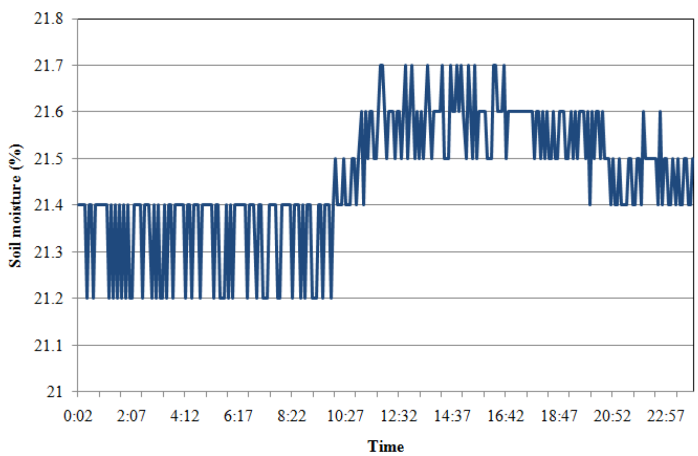


Figure 9. Soil moisture content in greenhouse for 1 day at every 5 min

Figure 10 show the illumination monitoring image in greenhouse from web camera. Left image show a normal condition which all light bulbs were turned on and operated in normal, meanwhile right image had several light bulbs out so the illumination was under unusual condition. Average pixel value of the captured image could be used as a decision factor for illumination alert system.

Figure 10. Light monitoring image in greenhouse from web camera: normal condition (left) and unusual condition (right)

In this paper, a remote monitoring system for protected chrysanthemum production was designed and the environmental information was monitored via CDMA technology so the farmer or producer which far away from facility could check essential environmental factor and confirm the results. Results of this research would be useful for construction and utilization of the final remote control system. However further study is needed to complete the integrated remote control system based on wireless sensor network. The next step of this study is to set the locations of optimum sensors for environmental control and provide a reference value of each sensor for remote control system. As a conclusion, we present future research issues related to the integration of wireless sensor networks with the remote control system for chrysanthemum production.

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