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Management System of Underground Water-Facilities using RFID

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Abstract

Among the present worldwide problems, lack of water resources and its supply is one. Recently, various researches has focused for the maintenance of tap water facilities for the purpose of effective use of water resources are being proceeded. Especially, since most of the tap water facilities are installed underground, maintenance using high technology is very important. We conducted the research for the development of system that can detect the early stage leakage from tap water pipe and minimize the inconvenience of users from cut off water, and can monitor and decide various information related to the facility maintenance of maintenance department fast using RFID. Tap water facilities maintenance system using RFID could detect the water leakage in it's early stage and supply the easiness of detecting the absolute, relative location of underground facilities to the facility manager and also, we could verify the possibility that can predict the abnormal operation. The use of ubiquitous was presented as a very important issue in not only the measurement but also in communication. Especially, the measurement of underground facilities require the reliable fast communication speed for the underground wireless communication system and since it is difficult to get the research data domestically, the situation is that we have to rely on the overseas technology unavoidably. The practical use of RFID and ubiquitous system that was applied the underground wireless communication system will bring a huge change not only on the future tap water facilities but also on the establishment of all underground facility maintenance system. It was verified to be contributable for detection and prevention of damage of tap water facilities as well as the conservation and effective use of water resources by detecting the water leakage in early stage.

Keywords: RFID, Underground water-facilities

INTRODUCTION

Recently, there was a spike in global interest in water resources. However, the aspect to secure water resources has its limit and huge amounts of money that are hard to imagine are accompanied in the cost aspect. Therefore, how the water resources, the finite resources, are effectively utilized become an important part of the recent studies. Studies on repetitive recycling of water resources have built institutionally organized built institutional reorganization and national support systems as the national issues of concern. However, the studies are less interested in efficient utilization plans through the prevention of leakage.

As most of the tap water facilities are laid underground and a lot of information is transferred by using the underground communication line under the influence of information, it is more difficult to maintain the tap water facilities. Therefore, the necessity to build the system that can measure the underground location of tap water facilities exactly and monitor them in real time without being influenced by other facilities is urgently needed.

According to this necessity, the study tries to help efficient maintenance of tap water facilities by using RFID that became the new concept for maintaining all kinds of distribution and facilities as part of the ubiquitous system which has recently continued to make rapid progress.

This study tries to make everybody mange the maintenance of the tab water facilities that are now depending on individual functions and experiences easily and effectively anytime and anywhere by utilizing ubiquitous systems U-monitoring. For this, the study plans to introduce the system that can monitor and maintain water valves and tap water pipes, the essential factors for their maintenance, by utilizing computer systems and GIS.

First, the purpose is to build high-dimensional active facility maintenance system that facility managers without experiences in advance prevent accidents by predicting and analyzing them as well as respond rapidly to them through ubiquitous systems and U-monitoring. Second, realistically, it is almost difficult to detect exact locations as most of the tap water facilities are laid underground. The existing metal or nonmetal pipe locators detect city gas pipes, communication lines, or power lines more easily rather than locations of tap water pipes. This leads to the result that causes damage of other facilities in business including the restoration of the water leak from tap water pipes. Therefore, the purpose of the study is to draw the method which can indicate and detect where each facility is buried exactly by minimizing mutual interference among facilities laid underground. Third, the

maintenance of all kinds of underground facilities is separately done by each institution by using the drawings and GIS systems. Integrated management of water and sewage systems and partial city gas pipes is done by local governments. However, the application history is insignificant due to uncertain locations. It's because there are big differences in methods to enter in GIS systems and it is difficult to secure accuracy. Therefore, the study tries to develop the system that can exactly and easily enter relative locations of each facility in GIS systems and draw a plan to improve input methods.

INTEGRATED MAINTENANCE PLAN

Real condition of underground facilities maintenance

Since the government promoted the graphic data maintenance plan for computerizing management of underground facilities to computerize the underground facilities management system (The Ministry of Construction and Transportation) as a demonstration project in 1997, the Ministry of Environment prepared the upgraded and mature foundation from the existing underground facilities maintenance plan by establishing (Water and Sewage Information Vision 2001 to2010, the Ministry of Environment, 2001).

The general departments that take full charge of GIS nationally are installed and operated in each local government. However, the number of persons related to civil engineering, land register, and geodetic survey with professional qualification that can measure locations of underground facilities exactly is only about 49.6% of all employees and the rest of them consists of administrative or computing jobs. Stuffing like this became the barrier to exact maintenance of underground facilities. However, it is thought that this problem cannot easily be improved unless the government has a strong will.

Monitoring locations of waterworks facilities using RFID

In order to seek for the plan that can monitor relative and absolute locations of underground facilities based on GIS, an experiment to seek for a plan to secure the degree of precision about monitoring locations of waterworks facilities using RFID(Radio frequency identification) which is gradually expanding the utilization field in each sector now.

Table 1. Resent condition of using RFID by frequency band.

Frequency	**Low frequency (LF)**	**High frequency (HF)**	**Ultrahigh frequency(UHF)**		**Micro wave**
	125kHz, 134kHz	**13.56 kHz**	**433.92 MHz**	**860~950MHz**	**2.45 GHz**
Recognition distance	Equal to or less than 60cm	About 60cm	About 50 to 100m	About 35 to 10m	About 1m
General characteristics	Comparatively expensive No degradation by environment	Inexpensive than low frequency Short recognition distance and multitag recognition is required Suitable for the application fields.	Long recognition distance Sensing environment including real time tracking, internal humidity of containers, and impacts, etc.	Can be produced at the lowest price due to development of IC technology. Multitag recognition distance performance is most excellent	Are most influenced by environment of the performance characteristics similar with 900MHz tag
Operation method	Passive	Passive	Active	Active/ Passive	Active/ Passive
Application field	Process automation Access control/Supplementation Animal management	Baggage management Library data management Transportation cards Access control/Supplementation	Container management Real time location tracking	Supply chain management Collect electronic tolls automatically	Anti-forgery
Recognition speed	Low ←----------→ High				
Environmental effect	Strong ←----------→ Sensitive				
Tag size	Large ←----------→ Small				

In this experiment, RFID was installed to be able to monitor location of facilities in the tap water pipes. For management of valves, the most important part among tap water facilities, a plan to be able to connect and operate data storable RFID to GIS systems by installing it tried to be advocated.

First, RFID of the LF band, the low frequency band of the passive method was buried on the upper parts of the tap water pipes at intervals of 0.3meters The result that tested and explored 20 RFIDs buried at intervals of 10.0meters has found to show accuracy as expected as the probability of detection was 100% and the plane error of the pipes is ± 0.075M. However, it can conclude that RFID must be installed in the upper parts of metallic facilities because the probability of detection of RIFD installed in the lower parts of the metallic pipes is relatively low.

For the study on the possibility that RFID is interlocked with GIS, the applicability to the field was reviewed by entering each RFID's unique serial number in the GIS system. RFID's unique serial numbers entered in the GIS system are based on 12 digits. Especially, giving unique frequency to each facility was set so that facilities can exactly be classified even though they are adjacent to each other. However, next method to complement this should be developed to classify maximum two facilities simultaneously as the number of frequency that the detector can simultaneously detect is limited.

It was very easy to manage RFID by entering its unique numbers in GIS. However, there were many problems to transfer GIS data to transportable computers to provide the function to be able to monitor them easily in the field. The most difficult problem became the factor that limits actual use as high Data volume of the GIS system.

Among the elements necessary for approaching U-monitoring that we seek, there is high probability that the security of the stability and speed of communication is the most important factor. Therefore, next studies on U-monitoring should secure the security of inexpensive, stable, and speedy communication systems by arranging them jointly with the communication field.

For next methods to monitor them in order to prevent underground facilities from being lost or damaged after installation, studies on the methods that can utilize facilities themselves as RFID should be arranged. For RFID utilized in the study, the recognition speed is low but stable. And RFID of the 134 kHz band, the LF band that the maintenance including power supply, etc. in the future, was used. Especially, two products released in Korea were tested because the security of the stability of underground communication is very important. However, as response rates of the Korean products in the depth of more than 0.6meters were very low as less than 30%, now Korean technical skills have the limit of underground communication. In case of Gwnagju, the average depth of buried tap water facilities was 1.0 meters. The average depth of buried cit gas facilities was investigated to be 1.45 meters. Therefore, RFIDs produced in Korea were excluded in the experiment because they are not useful. The experiment could not help being arranged just by using RFIDs produced 3M Company located in Naju, Jeonnam.

System to detect the water leak by monitoring water pressure

This study examined if GIS systems and water values can predict damage and the water leak of tap water facilities and provide them for managers as they are mutually interlocked with water-pressure gauges and flow meters.

For U-monitoring that can manage all kinds of data related to waterworks, the area that supplies tap water to about 2,730 households of the whole area of Jungheung-dong, Buk-gu, Gwangju was selected by way of showing an example. And the sensors that can measure water pressure were installed in 7 places, valves were 87 places, and flow meters were 6 places. And RFIDs which can indicate locations of pipes were installed in about 195 places. A plan to utilize radio communication was reviewed at the initial stage as the method to measure water pressure and transmit them to a central control system. However, it could not be applied to the study because the initial equipment costs and communication expenses were excessive. So the wire TM/TC method was used. And for continuing to arrange studies related on Green energy in the future, solar panels were installed in 7 places that water pressure sensors were done so that separate power cannot be required. In order to measure water pressure, data were downloaded and analyzed with the cable method using serial port.

It is thought to serve as a momentum to present the new direction about the possibility to be able to analyze the water leak with the method other than the volume as the upgraded method from the method which measured the water leak from tap water pipes by using water pressure and monitored the existing volume. However, the problem drawn from the course of study is that it was very difficult to develop the program that judges symptoms of the water leak as water pressure is very much changed depending on the number of users, the used volume of tap water, and the temperature changes over time. Especially, there were large quantities of the water leak and the water leak could be judged even after the patterns were analzyed in middle-sized tap water pipes that the diameter is equal to and more than 75m/m.

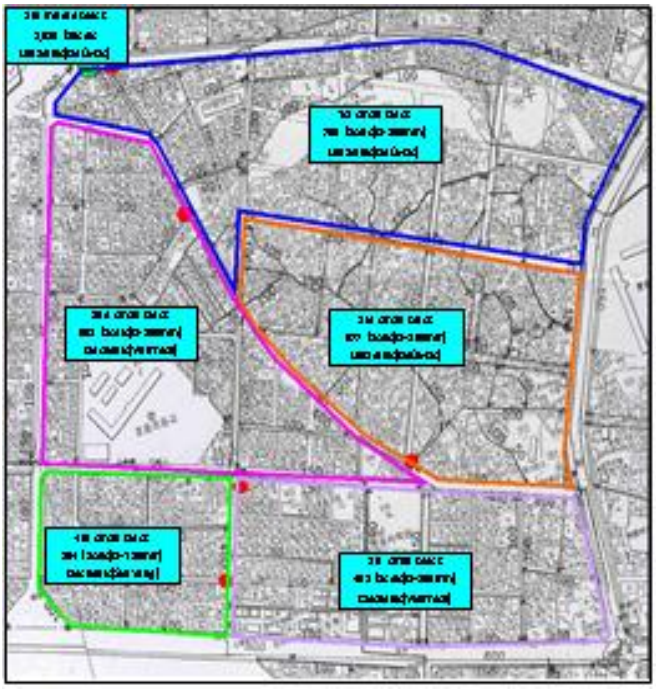

Figure 1: Present condition of building the discharge measurement systems in the whole area of Jungheung-dong, Buk-gu, Gwangju.

Monitoring these symptoms of the water leak can be recognized even after a large amount of tap waters is wasted. Especially, the water leak can be found in most of cases only when a large amount of water leak to the extent that people can find with the unaided eye due to the water leak exposed to roads.

The distribution network analysis is the very important item that makes or breaks the selection of the points that can show symptoms of the water leak under the influence of water pressure. Therefore, the interpretation result of the expert with many experiences in this field was cited (The distribution network analysis was conducted with the cooperation of Gwangju Jeonnam Branch, the Korea Water Resources Corporation).

Monitoring the water leak by doing rates of flow

For the prevention of the water leak until now, the water resources have been managed with the primitive method that found and restored it by using leakage finders or move out and restored it by report of it when it was exposed to ground. For these methods, the precious water resources are wasted and there are wide differences in the results according to the ability to detect the water leak by individual experiences. Therefore, this study arranged the method to find the water leak by monitoring rates of discharge in real time and promote projects to prevent it effectively.

In order to measure rates of discharge, the grid block pipe network was created in the whole area of Jungheung-dong, Buk-gu. And a block was built based on 304 to 790 customers to promote efficiency and flow meters were installed. In order to analyze the degree of precision of measuring discharge, ultrasonic and electronic flow meters were used except the mechanical devices as the measurement method.

The degree of precision of measure discharge is very important to select flow meters, but it is more important to select proper pipe sizes. In order to select the flow meters of proper pipe sizes that can maintain minimum water pressure within the range to satisfy maximum discharge per time, the proper pipe size was calculated by using a EPANET-program and the flow meters one level down from the pipe size was selected and installed. As a result, the case that the flow meter of the same size with tap water pipes was installed could be found that the probability to be able to predict the water leak at night is remarkably high. Therefore, in order to monitor the water leak by doing discharge, the flow meter with smaller pipe size than that of pipes must be installed. Or if researchers can afford to buy more, it is judged that two flow meters with different pipe sizes are installed so that the method to measure discharge from each flow meter by setting a period of time can be introduced. Because the purpose of monitoring is to find the water leak from tap water all kinds of information should comprehensively be analyzed as the analysis on patterns to measure minimum discharge at night and use discharge are programmed.

The results that conducted pattern analyses on graphs to analyze the water leak per 1, 3, 5, 10 minute have found that the forms of analyses on the water leak per minute are too various. So it is judged to be improper because there are too many factors which cause confusion in predicting symptoms of the water leak. Prediction of the water leak was roughly possible by the analysis on data to measure discharge per 10 minutes. The most suitable analysis on discharge is judged to be possible in the analysis per 5 minutes. Therefore, next analyses on discharge and monitoring it will be appropriate to manage data per 5 minutes.

In order to improve the degree of precision in monitoring discharge, analyses on patterns of the amount of tap water used after creating blocks are very important. Because each different pattern is shown depending on weather, temperatures, and humidity, analyses on use patterns of, at least, more than one year should be done and each customer information should be utilized by connecting it to programs to analyze the water leak.

The pattern of the amount of tap water used that we analyzed is the average numerical values of the arithmetic mean of the whole City of Gwangju. And the amount of tap water used by the central business area, residential area, and business facilities area varied quite a bit.

A series of work that is mutually connected like this was built into an integrated system by utilizing a GIS system. The GIS system has found to increase users' ability to recognize space and utilization by showing spatial data visually. In order to grasp the amount of tap water used in a certain area utilized in the study, the customer numbers of the fare information system were squared with those of the GIS system. They were mutually connected to upload the amount of tap water used per month.

The maintenance of water valves of waterworks using RFID

Among the waterworks facilities, water valves play the most important role in emergency. However, it is true that the maintenance is neglected. This is also an example that well represents the characteristics of inefficient public systems in the aspect of utilizing human resources as well as the structural problem of them and organizations.

In order to solve this problem, RFIDs were installed on water valves. And in order to monitor their operational situations in real time, data storable RFIDs (Hereafter, referred to as ID-typed RFID) were installed on 1,500 major water valves with the diameter of more than 250m/m in Gwangju. For the installation methods, three types were experimentally installed. Type 1 is the method to bury RIFID 0.6m under the ground from the points located 20cm due north of the water valves. Type 2 is the method to install RFIDs by using rings in water valve chambers. Type 3 is the method to install ID-typed RFIDs of the pin-type on roads of the upper parts of the water valve chambers. The characteristics of the results that analyzed each type's detection ability and maintainability due to next road repairs and overlay work were as follows:

For type 1, there were frequent cases that RFIDs were damaged or lost as all kinds of construction works were arranged near the water valves as they were installed under the ground next to them and the probability of detection was almost 100%. However, it took some time to record information and there was some error according to environment in the upper parts. Therefore, the method to bury RFIDs next to water valves is judged to be the undesirable installation method due to inaccuracy of indicating locations and error of information records.

For type 2, among 1,300 RFIDs, the ID-typed RFIDs applicable to 1.7% could not be detected in 22 places. The result that analyzed the cause was investigated to be because of disrupting the formation of magnetic fields as they were installed in the metallic supports of water valves. As the problem like this was found, the installation of ID-typed RFIDs in the water valves using rings in them is judged to be undesirable.

Type 3 was the method suggested as an alternative for solving the problems of Type 1 and 2. It showed the most excellent ability to detect the water leak and store data among the methods which were experimentally installed until now. The installation method is simple, but satisfied ID-typed RFID functions with signs of tap water pipes. The probability of detection has perfect performance as 100%. In order to test a case that 30cm was overlaid in pavement of roads, the result that tested exploration after asphalt concrete of 30 cm was installed on the upper part of the ID-typed RFID has found that the excellent exploration ability was displayed. And as it was investigated to play a role of calling waterworks facilities' attention, it is judged to be useful to protect them.

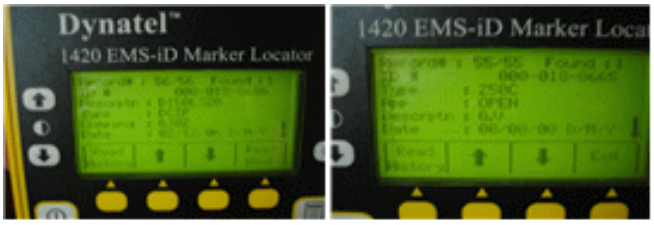

Figure 2: Screens of Pipe line-typed and ID-typed RFID detectors.

Locations and dimensions of valves were entered in the GIS system by using water valves and ID-typed RFIDs. The system that monitors the water leak in real time by connecting it to the water flow rate management program was built. Next water flow rate management programs are expected to build the intelligent system that judge and block the water leak by themselves based on U-monitoring and ubiquitous technology.

The U-monitoring technology is essential to build the systems that can recognize and manage underground facilities by themselves in the ubiquitous age. And the basic data for U-monitoring should thoroughly be recorded and managed from now on.

CONCLUSION

The maintenance technology by monitoring underground facilities permanently is the very difficult field of study among the U-monitoring technology field. However, interest in the maintenance of this technology has been higher because its utilization gets higher in real life as its information has rapidly been arranged. Therefore, the study tries to suggest the method to maintain underground tap water facilities using RFID, the technology which can be an innovative turning point in the maintenance method of water works facilities among underground facilities.

First, infrastructure that underground communication is possible should be equipped to measure abnormal behaviors of waterworks facilities buried underground. If partial

infrastructure is equipped in the study, the mixed method of short-range wireless communication and wire communication is judged to be useful as the alternative. This result could suggest the possibility to recognize and control abnormal behaviors of underground facilities in readiness for the ubiquitous age.

Second, the RFID-buried method for grasping locations and information of underground tap water facilities will be a useful example in management of other facilities. And if property data including exact locations and dimensions are managed by installing RFIDs so that they can be connected to the GIS systems that each local government, institution, and private business operator are operating when underground excavation work will be done for maintaining all kinds of things, it is expected to make an innovative contribution to the maintenance of underground facilities in the future.

REFERENCES

[1] Ministry of Construction and Transportation (**2005**), "Present condition of building GIS in underground facilities", pp.3-7.

[2] Ministry of Construction and Transportation (**1997**), "the graphic data maintenance plan for computerizing management of underground facilities to computerize the underground facilities management system", pp.105-151.

[3] Gwangju (**2008**), "Gwangju Master Plan for development of water supply Vol. 1, pp.363-368.

[4] Kim, Gye-Hyeon (**2000**), "GEOGRAPHIC INFORMATION SYSTEM". pp. 396-405.

[5] The Ministry of Environment (**2001**), "Water and Sewage Information Vision", pp.68-95.

[6] Marker Placement Recommendations (**2005**), "Detailed Guidelines for Implementation of Electronic Marking" (http://www.3m.com/dynatel)

[7] NULCA (National Utility Locating Contractors Association) NEWS (**2009**), "3M Electronic Marking System- Save Time and Money Locating Underground Assets" p.4.

[8] Oil & Gas Journal (**2006**), "Programmed Route Markers Improve Efficiency Safety".

[9] Position IT Magazine - South Africa (**2007**), "GPS Improves Utility Management Operations", pp.74-75.

[10] Underground Construction Magazine (**2004**), "Government Facility Optimizes Underground Location Accuracy for Safety, Efficiency".

[11] Underground Construction Magazine (**2007**), "Electronic Markers Simplify Construction of Gas Lines", p.31.

[12] Water World (**2005**), - Internet Edition "Municipality Marks New Pipelines for Future Access"