Design of Water Quality Measurement Sensor Robot based on Wireless Communication Environment

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Abstract

Real-time continuous provision of information on the field of the monitoring of water environment with wireless communication technology is a method to monitor the sources of water pollution in a systematical way. In particular, an unattended measurement device on the water environment information collects the data that can be obtained from a remote place in real time and enables significant improvement in reliability and communicability. Therefore, in this paper designed a sensor robot to recognize location with GPS and control it from a remote place and then transmit the measured water quality information in real time with wireless communication.

Keywords: *Wireless communication, Sensor Robot, GPS, water quality measurement*

1. Introduction

In this 21st century when the advanced welfare society depends on the improved quality of life through environment, reduction measures for the environmental management as the first priority are being urgently prepared in solving water environment data issues that are significant. However, only if we can prepare the reduction measures that are based on the reliable data and accurate water pollution level, we can overcome the excessive waste of pollutants-reducing cost and the efficiency of environmental pollution control[1, 2].

In addition to the pollutants-reducing measures, the environmental pollution data collected from the stage of making national environmental policies or decisions is important. More importantly, we should collect environmental data that can be used to predict sources of pollution and analyze the future trends. To this end, our role of analyzing and measuring environment is critical. For this reason, various organizations and institutions are sharing environmental data periodically by spending big budgets. Many countries have devoted themselves to the infrastructure construction for collecting environmental measurement data through many researches and investments, and are now collecting and analyzing nationwide data based on this system [3-5].

In this paper designed the Remote Control Module that enabled remote control and data transmission in designing a water quality sensor robot system and Robot Platform that is freely movable based on the prime and secondary power on the water. The total power consumption of the robot platform was predicted by calculating the power consumed per day considering the hours of use per part, and the displacement capacity[1] and water line[2] were

[1] The amount of fluid that was excluded due to an object when the object floats in a fluid
2 The line on which the platform sinks under water

calculated by considering the weights of used parts and platforms, so that they could be in stable operation without being sunk to the water. Inside the platform were fixed 12 V battery of prime power, Remote control Module, drive head, and other devices.

In addition, external sensor holes were provided so that various measuring devices could be connected depending on the source of water environment pollution and the control system connected to GPS was designed to increase the location-based environmental information monitoring, establish standards, and increase availability analysis.

2. Related Reaserch

2.1. Water Quality Monitoring System

The existing water quality data monitoring system contains sensor node controller to collect water quality sensing data (pH, dissolved oxygen, turbidity, temperature, electric conductivity, and chlorophyll), relay nodes including ZigBee module and CDMA functions, interface to transmit the information collected from the sensor nodes into the wired network, and transmission of an alarm to an administrator via SMS when the amount of data exceeds the standard [10]. However, the water quality monitoring system that has been developed so far was only a development of technology for analyzing both the fixed sensor model and the data collected. We still lack of researches on the GPS-based mobile sensors, as shown in this study, and the remote control system.

2.2. Data Transfer Technology

Recently, water quality data measurement and collection technology has transferred from the measuring devices and wired modes to sensor measuring devices and radio transmission, and thus measuring devices are becoming smaller and wireless transmission devices are becoming smaller rapidly and less power-consumed. The size of wireless communication module that is responsible for the size of sensors and the amount of data transmission in terms of smaller measuring equipment and device occupies the largest portion.

The system that constitutes the measuring devices for monitoring environment including water pollution can be largely divided into sensor part that performs measurement, SoC part that analyzes signals obtained from the sensor, and data communication part that delivers the processed data to the central collection unit including server. Especially in SoC part which is responsible for signal processing, one integrated circuit(IC) or a few of ICs can be implemented into the form of SiP(System in Package) using the semiconductor process technology.

Data transfer technology can be largely divided into device technology and wired/wireless data transmission technology, and each technology can be re-categorized into segmentalized technologies and the device technology is again classified into SoC, MEMS, and nanotechnology. Device element technologies are shown in Table 1.

Table 1. Data Transfer Technology

Technical Details	Definition
SoC (System on Chip)	- Microprocessor, digital signal processing device, memory, baseband chip, and embedded software are accumulated so that the chip itself can act as one system. - A combination of core IT technology that system formation technologies and semiconductors are designed and manufacturing technologies
EMS(Micro Electro Mechanical Nano Technology	- A technology that commonly means too small three-dimensional structures and technologies to implement these structures - A technology that designs, manufactures, and applies smaller parts and systems in micro unit by combining electronic(semiconductor) technologies, mechanical technologies, and optical technologies.
Nano Technology	- A generic term of the technologies to represent new functions and outstanding characteristics using the nano's unique specificity by controlling the structures and arrangements of materials through the manipulation of nm-sized atoms and molecules - A technology to identify and control the characteristics of materials at a nano scale

A wired/wireless data transmission technology can largely be divided into "wired" and "wireless," and wireless is again divided into WLAN (Wireless Local Area Network) and WPAN(Wireless Personal Area Network). The technology classification depending on the wired/wireless data transfer technology is as shown in Figure 1.

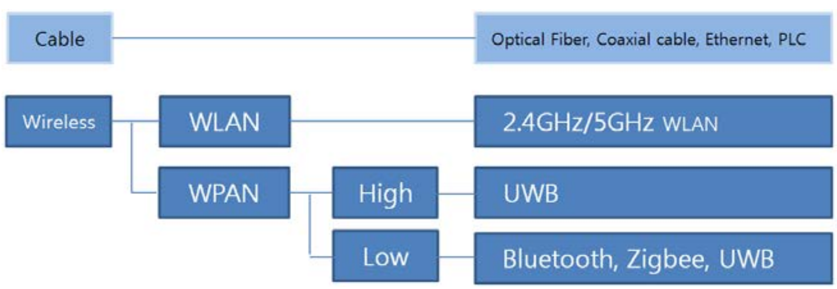

Figure 1. Wireless Data Transfer Technology

The characteristics of frequency range, transmission speed, and transmission distance by each data transfer element used for wireless technology is as shown in Table 2.

Table 2. Wireless Technology Analysis

	Frequency range	Transmission Speed	Transmission distance
WLAN	2.4G/5G	54M/600Mbps	50m~10Km
UWB	3.1 ~ 10.6G	54M/600Mbps	10m
Low UWB	3.1 ~ 10.6G	1Mbps	50m
Bluetooth	2.4G	1Mbps	10m
ZigBee	868M/916M/2.4G	250Kbps	30m

3. Design

3.1. Remote Control Module Design

The controller module that is responsible for the remote control of sensor robot designed in this study is as shown in Figure 4. It has 8 input ports, 8 output ports, RS-232C standards, and TCP/IP. In general, water quality measuring devices are complying with the RS-232C standards and so the devices were designed in consideration of the future TCP/IP support. And so Firmwave was designed so that each operating mode could be set up.

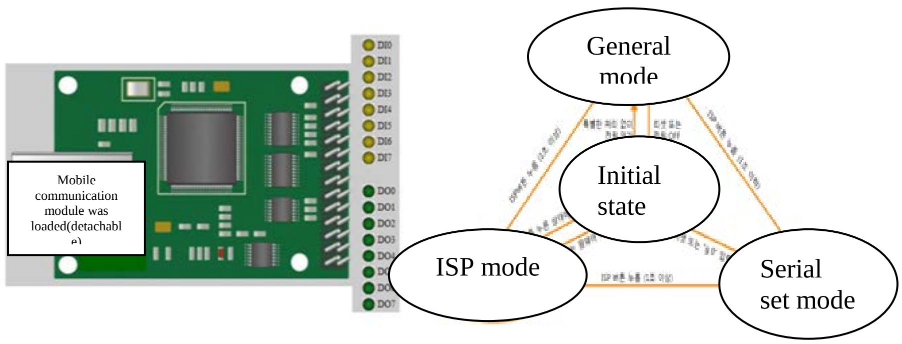

Figure 4. Remote Control Module Design

3.2. Sensor Robot Design

Sensor Robot is boat-shaped and runs on the water. 12v battery is utilized as a main power and 60W Solar Cell as a secondary power. It was designed as an integral platform by considering the collision and water proofing on the water and a propeller-typed motor was loaded on the left and right to make a fast propulsion and redirection. The top was covered with a solar cell and used as a secondary power and the frontal top and bottom side could be connected to a camera or a sensor. GPS and antenna for wireless communications were installed into the rear top. For an easy movement, 4 grips and 2 left and 2 right sensor holes were provided so that they could connect water quality measuring sensors and other devices. Figure 5. shows the sensor robot that was designed.

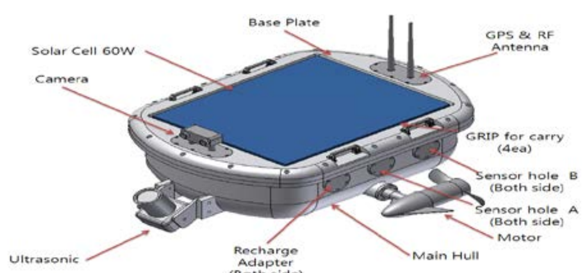

Figure 5. Sensor Robot

Space was obtained so that the inside of the sensor robot could contain Remote Control module, GPS module, modules for use in wireless communications, and battery – a major power - and circuit plate was manufactured for an easy fixation. Figure 6 is a structure that was designed by each part of sensor robot. It shows the location of circuit plate for fixation and internal spatial structure.

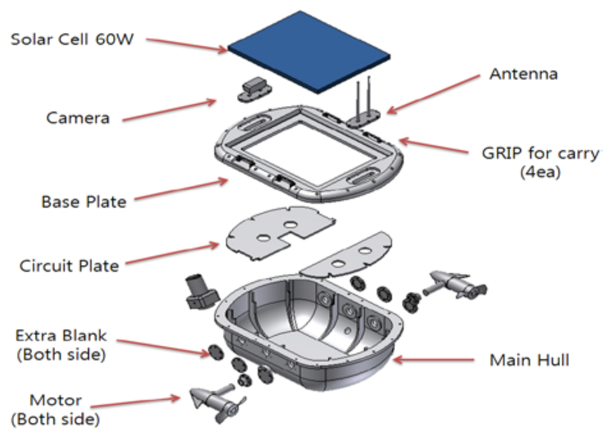

Figure 6. Robot Platform Internal Structure

Table 3 calculated daily consumption power(Wh) based on the power consumption of each part (W) and daily hours of use(h). When driving motor was used for 4 hours on the basis of about 20W, the daily power consumption was 80Wh. When Remote Control Module was used for 8 hours with about 3W consumption, the daily power consumption was 24Wh. When camera/GPS module was used for 8 hours on the basis of about 2W, the daily power consumption was 16Wh, when the module for use in wireless communications was used for 8 hours on the basis of about 3W, the daily power consumption was 24Wh.

Table 3. Daily Power Consumption

	Consumption power(W)	Daily hours of use(h)	Daily consumption power(Wh)
Driving Motor	20	4	80
Control module	3	8	24
Camera/GPS module	2	8	16
Modules for use in wireless communications	3	8	24
Others	7	5	35
Total			**179**

The other parts were based on 5 hours with about 7W of consumption power. The daily consumption power of the entire platform is predicted about 179W.

Formula (1) calculates displacement capacity and water line so that the platform cannot sink into the water. Displacement capacity is the amount of fluid excluded due to an object when the object floats in the fluid and calculated like the below formula.

$$\nabla = \gamma V = 1025 \times 0.135 = 138.375\,[kg] \quad (1)$$

. ∇: Displacement capacity (kg) , γ: density of water, V: volume of the shape(kg/m^3)

Water line is the line that the platform sinks into the water. The displacement capacity calculated in formula (1) is 138.375kg. So when it exceeds this, the platform sinks into the water. Formula (2) calculates the water line with the ratio of load on the basis of the displacement capacity. The total weight of the platform was 90kg(Body:30kg Battery:20kg *etc.*,:40kg)and the formula that is used to calculate the water line by the weight ratio is as follows.

$$T = \frac{w}{\nabla} \times H = \frac{90}{138.375} \times 360 = 0.65 \times 360 = 234.14[mm] \quad (2)$$

* WL: water line, ∇: displacement capacity[kg], w: load to be added to the body [kg],

H : Maximum height of the body

Figure 6 shows the line that the sensor robot calculates in the above formula, and 234.14mm from the bottom sinks into the water and it can float without sinking into the bottom.

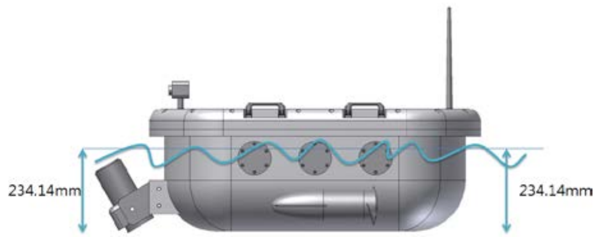

Figure 6. Line that the Sensor Robot Sinks to the Water

3.3. Wireless Communication Method

The wireless communication module designed in this study was made to enable long-range communication by considering various types of external environment depending on distance. Figure 7 is a 802.11bgn-sized 2.4GHz WiFi module, which allows high-speed long-distance transmission.

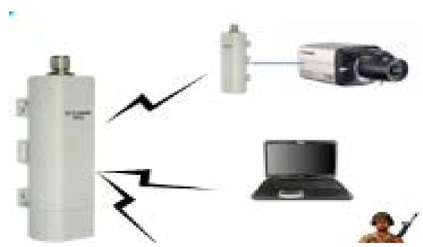

Figure 7. Wireless Communication Module

3.3. Prototype Design

The sensor robot designed in this study is as shown in Figure 8 To look at the full size of the sensor robot, it’s 1,000mm long, 730mm wide, and 360mm lengthwise. This size is easily movable with a car or a cart. The total weight is about 90kg, which can be easily moved by 2 adults. 60W Solar Panel was attached to the top for fixation of a camera or GPS/wireless module antenna. It was made to be connected to the front with underwater camera, ultrasonic sensor, and sonar sensor, and various sensors could be expanded through propulsion propellers and two holes in the left and right. The functions of this Sensor robot are as follows.

-Connectible to the sensors that can measure various water environments plus video interface

-Water treatment with the front ultrasonic waves and plasma sensors

-Long-distance data transmission and remote control using the wireless communication network

-Smart management with easily movable measurement equipment rather than stationary measuring equipment

Figure 8. Sensor Robot Prototype

The internal structure of sensor robot is as shown in Figure 9 The inside of sensor robot is connected to the Remote Control Module for power supply, input/output system, water quality-measuring sensor module, control of propulsion and driving section, and remote control for fixation. Battery is installed in the bottom center of the platform, and the propeller controller is attached to the left and right on the basis of battery. To secure and install Remote Control Module, input-output device, and other additional work spaces, circuit plate was installed on the top of the battery for fixation.

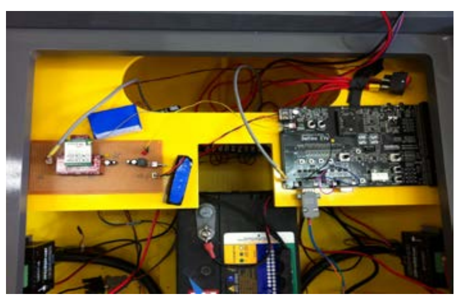

Figure 9. Internal Structure of Sensor Robot Prototype

4. Discussion

To verify the performance of the platform proposed in this study, GPS coordinates and space information of a pond were obtained in advance and experiment was conducted based on the transport speed of the platform.

In the experimental environment, GPS module used the products that were commercialized with A3 for location measurement. The distance of the platform to the remote control system was 30m. The system requirements of start, forward, stop, backward, right turn, and left turn were compared with GPS error rate on the basis of 5 times of trials. The remote control system was implemented in Windows XP based on C++.

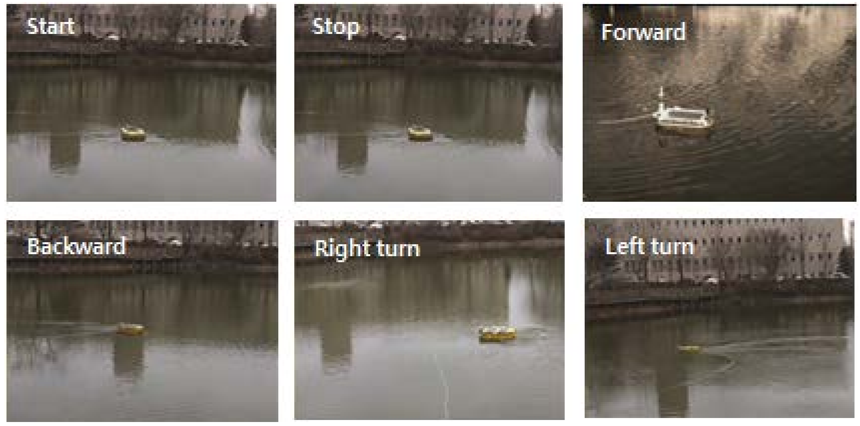

Figure 10. Platform Operation

As shown in Figure 10, platform operation was found from the remote control system and an order of start, forward, stop, backward, right turn, and left turn was commanded. The delay time of instruction execution rarely occurred, but in case of location error rate, already obtained information of a pond space showed about more or less 1.5m of error (on average) with the experimental coordinates. This seems to be attributable to the performance difference of GPS module. So, to reduce the error range, it is necessary to make a research on the position correction through real-time commands from highly-performed GPS module and remote control system.

To indicate the location of a moving platform on the numerical map, it is necessary to database spatial data(space information of a pond) and non-spatial data(location information of a moving object), and the error part of this location information is considered to reduce the error rate of location information by providing an already obtained spatial information management system.

5. Conclusion and Future Work

This study proposed a movable sensor robot that could be used to solve problems in order to acquire real-time information in the field of the existing water quality environment monitoring and limit the measuring areas and proposed a location-based GPS and remote management system to acquire real-time reliable information and take a very systematic monitoring on the pollution status of water quality.

In the proposed platform, sensors on pH, DO, electrical conductivity, temperature, and degree of muddiness are commercialized and sold a lot, but the platform was configured in the detachable form in a movable environment to solve poor penetration and high prices.

In the future research directions, more researches should be performed to design an intelligent algorithm for the autonomous vehicle of sensor robot and mobile-based smart management system and scheduling. And a technology to enable data collection through additional interface like video materials is also required.

Acknowledgements

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