Design of In-situ Self-diagnosable Smart Controller for Integrated Algae Monitoring System

Sung Hwa Lee, Vinayagam Mariappan, Dong Chan Won, Jaekwon Shin, Seungyoun Yang

1 Department of Telecommunication & Information, Cheju Halla University, Seoul, Korea
2 Graduate School of Nano IT Design Fusion, Seoul National Univ. of Science & Tech., Seoul, Korea
3 Pangaea21 Co., Ltd., Seongnam, Korea
4 Fivetek Co. Ltd, Seongnam, Korea

hwa2@chu.ac.kr, vinayagam_m@hotmail.com, fecal@pangaea.co.kr, †neosya@fivetek.co.kr

Abstract

The rapid growth of algae occurs can induce the algae bloom when nutrients are supplied from anthropogenic sources such as fertilizer, animal waste or sewage in runoff the water currents or upwelling naturally. The algae blooms creates the human health problem in the environment as well as in the water resource managers including hypoxic dead zones and harmful toxins and pose challenges to water treatment systems. The algal blooms in the source water in water treatment systems affects the drinking water taste & odor while clogging or damaging filtration systems and putting a strain on the systems designed to remove algal toxins from the source water. This paper propose the emerging In-Situ self-diagnosable smart algae sensing device with wireless connectivity for smart remote monitoring and control. In this research, we developed the In-Site Algae diagnosable sensing device with wireless sensor network (WSN) connectivity with Optical Biological Sensor and environmental sensor to monitor the water treatment systems. The proposed system emulated in real-time on the water treatment plant and functional evaluation parameters are presented as part of the conceptual proof to the proposed research.

Keywords: Water Treatment System, Algae Blooms, Integrated Algae Monitoring System, Wireless Sensor Network (WSN), Biological Sensors, Hyperspectral Remote Sensing, Remote Terminal Unit (RTU)

1. Introduction

The natural environmental pollution degrades the quality of surface waters around the world and create lot of human health issues due to anthropogenic sources such as fertilizer, animal waste or sewage mixed with water and this leading to severe degradation that may preclude their long-term use. This water degradation include the occurrence of toxin producing phytoplankton, like cyanobacteria. These events in water source can cause human health issues such as the poisoning of seafood and the closing of recreational waters, but they also pose challenges to water treatment systems. In water treatment systems algae blooms in the source...
water can affect drinking water taste & odor while clogging or otherwise damaging filtration systems and putting a strain on the systems designed to remove algae toxins from the source water. So In-situ monitoring and removal of algae toxins is most important to save the life of livings consume the water.

The microalgae cell wall and How to degrade the cell wall using Ultrasound based water pretreatment methods is described in [1]. In this approach describes the detailed HW design details and system specification of Ultra-sonication based pretreatment system. The Fluorescence analysis and Optical biological sensor design for effective Phycocyanin parameters measurement to find the water quality is described in [2]. As all know, fluorescence for a given cell concentration is affected by a number of factors including; the amount of light the cell was exposed to prior to the measurement and variation amongst different species, physiological states and environmental conditions. All these approaches only explaining about water treatments based on the site request not about online monitoring and diagnosing instantaneously.

The Smart Environment monitoring of the physical world that is richly and invisibly interleaved with sensors, actuators, displays, and computational elements, embedded seamlessly in the everyday objects of our lives, and connected through a continuous network. There are many research works that contributes to solve various issues in Smart Environments, such as seamless access to resources and devices, distributed service executions, social choice techniques [3]. Other works explains how IoT is based on three paradigms - internet-oriented, things oriented and knowledge-oriented [4, 5].

The complete IoT based smart water management model is proposed on [6, 7]. In this work, the Internet of Things-based model for smart water management using OPC UA is described with detailed architecture in which consider the IoT technologies for decoupling decision support systems and monitoring from business processes coordination and subsystem implementation. This functional architecture considers several layers and interfaces to enable layer interaction. All these approach explain only about water management remotely and never discuss the online water treatment in-site.

This paper propose the in-sit self-diagnosable smart water treatment plant controller for online water treatment plan and real-time algae monitoring. The proposed study remote terminal unit (RTU) describes the real-time network-based data transmission system that can be applied to a water treatment system with lower sensor device and real-time data transmission technology with higher control center.

2. Remote Monitoring of Water Treatment System

The lack technology standard for remote water management related Information and communications technology (ICT) prevents a water quality management, effective interoperability, and increases the cost and the maintenance of water treatment plan. Nowadays the wireless sensor network (WSN) play major role all real-time remote system monitoring on all king of environmental condition from home to oceans. The Figure 1 illustrate the real-time scenario of wireless sensor system configuration.
The communication technology is a heart of building WSN that constructs the network includes various communication technologies such as LAN, Wi-Fi, LTE, WCDMA / CDMA, ZigBee, Bluetooth and Serial communication.

There are many small and local producers of specific solutions in a weak and fragmented market of the water treatment. The almost no adoption of complex and interoperable systems jeopardizes the control and monitoring of water treatment distribution networks, preventing also their evolution and necessary improvements, as an adoption of WSN paradigm. This paper propose an adoptable RTU design for remote water treatment monitoring with built-in diagnosis on controller. The Figure 2 illustrate the adaptive WSN architecture for water treatment system...

![Figure 2. WSN Architecture for Water Treatment System](image)

### 3. In-Situ Self-diagnosable Smart Remote Terminal Unit

The design of a dedicated smart controller RTU build with sensors, wireless connectivity, self-diagnosis, and automatic control system logic for each type of cyanobacteria algae in water source. The RTU sense the information and diagnosis the sensor information to start water treatment as well as transfer the information to remote monitoring system. The RTU design architecture is as shown in Figure 3.

![Figure 3. RTU Architecture](image)
The In-Situ Smart RTU product design with self-diagnosis usage model is shown in Figure 4. The smart RTU built-in with embedded sensor node, data processor, process control, submersible sensor, environmental sensor, and security surveillance image sensor.

![Figure 4. In-Situ Smart RTU Usage Model](image)

The embedded sensor node unit used to phycocyanin sensor data reception, environment sensor data collection, and security sensor data collection. The data processor unit process the phycocyanin concentration data. Receive data correction/correction, processing and conversion Data transmission via various communication I/F. The Process control section used to Sensor up and down driving and process control for measuring Phycocyanin concentration by depth (cleaning control, compressor control, etc.).

4. RTU Real-Time Emulation Results
The RTU design data processing part H/W module is configured as a miniature modular type so that it can be mounted on the embedded sensor node easily. The Smart Controller RTU embedded sensor node module is designed using STM32F103xx MCU. The RCU is connected with various sensor modules to receive information on the environment and information on the operation status of the integrated console.

![Figure 5. In-Situ Smart RTU PCB Model](image)
The designed self-diagnosis type Smart Controller RTU embedded sensor node module detects ambient temperature, illuminance, power, DOOR, fire status and transmits measured data. In case of inappropriate situation, prevents erroneous operation due to the surrounding environment and prevents accidents in advance. The designed In-Situ RTU PCB model is shown in Figure 5.

The data processing unit H/W module is based on STM32F103xx MCU with Cortex-M3 core. The STM32F103xx MCU is driven by a 72MHz system clock source, which shows sufficient performance in the processing speed of the sensor data to be measured and monitored in this study. The STM32F103xx MCU can be configured with up to 96KB of SRAM and 1MB of Flash memory, a high performance processor with USB 2.0 port, industrial CAN communication port, IEEE1588 compliant Ethernet port, built-in RS232C port and I2C port for external devices.

The data processing unit acquires the phycocyanin density data, performs calibration / correction processing for the accuracy of the acquired data, converts the data into a form recognizable by the control server, and transmits the data through various interfaces and processing. The data processing flow is shown in Figure 6.

Figure 6. Data Processing Flow Diagram

The designed proposed system monitor the environment condition and water algae condition in real-time then performs cleaning control instantaneously. This prevent the water quality condition online so that water not getting degraded and make human safe uses of water.
6. Conclusion
In this paper, presented the design of In-situ self-diagnosable Smart Controller for Integrated Algae Monitoring System using Cortex-M3. In this research, we evaluated and prevent the water quality degradation using temperature, illuminance, power, DOOR, fire, phycocyanin sensor to monitor the environmental pollution using WSN. This proposed water treatment management plant impacts on several key matters of human lives and several scenarios, such as cities, natural areas, agriculture, etc. and helps people to be healthier when they use water. The sensed information transmitted to the control room to monitor and allows people to take emergency prevention without affecting normal usage of water and aids to develop healthier society.

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