An integrated system of mobile application and IoT solution for pond monitoring

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Abstract. The current progress of information and communication technology has been critical to the development of the Internet of Things (IoT) in a aquaculture system. IoT solution in this system utilizes interconnectivity between devices to obtain fish pond monitoring data from sensing devices and then transmit the data to a remote server to be analyzed for decision-making in pond management. In this paper, we propose a smart pond IoT solution that provides a continuous and real-time pond monitoring. The system principally embeds five sensors that measure critical environmental parameters to determine water quality: temperature, pH, dissolved oxygen (DO), total dissolved solids (TDS), and salinity. The IoT solution also integrates the development of a mobile application on the android platform that allows remote monitoring capabilities for users to maintain efficient pond management. The application is designed with a friendly-user interface that helps the farmer to monitor sensor measurements, manage fish production cycle, record fish feeding schedule, and also monitor the health status of fish from multiple ponds.

Keywords: Aquaculture, Internet of Things, Mobile Application, Pond Management, Smart Pond

1. Introduction

Aquaculture is a farming activity for breeding and rearing aquatic organisms (either animals or plants) to increase their farming yield, which is implemented in the form of regular feeding, protection from predators, water management, etc [1]. The cultivations of the aquatic organism can be performed in various types of water environments such as artificial/natural ponds, rivers, lakes, and ocean. Indonesia is considered one of the countries with strong economic potential in the sector of fisheries. This is also in line with the national demand for fish and fishery products that has been growing over many years. Aquaculture can become a driving force to strengthen marine and fisheries economic developments and support national food security in Indonesia [2]. Therefore, the advances of the fast and effective aquaculture technologies are urgently needed to make up the demands, especially the developments of water monitoring technologies. The monitoring system becomes an immediate
primary concern as the fisheries sector can be heavily impacted by the rapid changes of environmental conditions such as pollutants since the ingested water is used by fish for the respiratory system [3]. Moreover, the overall health status of fish is determined from water environmental parameters, namely temperature, dissolved oxygen (DO) concentrations, pH, and total dissolved solids (TDS). Describing in detail in [4] and [5], freshwater fish such as striped snakehead fish (Channa Striata Bloch 1793) rely on the ideal environment with strict water conditions where the spawning, the rearing, and the maturation process, requiring the fish living in a man-made ecosystem to maintain water temperature, salinity, pH, TDS, and DO level at certain ranges to survive and grow optimally. This observation demonstrates that cultivating specific aquatic species also needs to have a very specific optimal control of environmental conditions with continuous care and maintenance. In this regard, real-time monitoring of water conditions plays an important role to maintain the proper management of water quality in ponds. The proposed monitoring system is a wireless sensors network where each sensor is placed in the monitoring area to measure, gather, and transmit information about the water parameters [6].

The deployment of smart Internet of Things (IoT) system enables the sensors to collect data and share the real-time information to a remote server and notify the farmers for any intervention in decision making. In our previous work, we have implemented an IoT pond solution targeted specifically toward the cultivation of the striped snakehead fish, although the proposed system can also be used for various aquatic organisms accordingly with proper adjustments of pond parameters.

In our previous IoT solution, we have demonstrated the development of web based application integrated into our IoT device to transfer data from sensors to a remote server [5]. The interconnectivity of devices in the remote monitoring system is appealing because the IoT development can also be integrated with applications in mobile devices, including smartphones, thus allowing more flexible mobile monitoring capabilities. This mobile system helps the farmer to manage multiple fish ponds from a mobile device. In this paper, we present the IoT solution that upgrades the previous solution to deploy a mobile application development designed for the remote pond monitoring. The application is implemented in Android platform and is called Nusapond. The application has a variety of monitoring tasks with a friendly-user interface, allowing users to manage multiple ponds in several designated pond sites that are integrated into our smart pond IoT project. In addition, we also improve the design of the current IoT prototype that utilizes solar panels that can reduce the cost needed to power the system continuously.

2. Related Works

The advances of information technology have significantly transformed the efforts to improve sustainable technology implementations. There are many examples of effective applications of information system that are deployed in a wide variety of fields, ranging from agriculture [7–11] to public health [12]. With advancements in information technology, data can now be gathered on location and distributed over a wide region using the Wireless Sensor Networks (WSN) and the Internet of Things (IoT). The major benefit of IoT is the ability to exchange data and remote control (mobile monitoring) of an object that we track by implanting sensors into the object (e.g. temperature sensors, inertia, etc.) [13].

Pond management based on mobile application has been implemented in many studies about pond water maintenance. Idachaba et al. implemented a system for managing catfish ponds that utilizes a pond controller consisting of water quality control sensors, a fish feed system, and a pond water change system [14]. The pond manager accesses closed-circuit television (CCTV) cameras which are then sent on a mobile application with pond controller and the sensors to maintenance water management, water changing system, feeding system, pond controller, and equipped with pond manager application. Another application called IoT-based water quality monitoring system was implemented for blue swimmer and mud crab farming [15]. It consists of small embedder devices multiple water quality sensors and wireless interfaces. The network uses a lightweight Message Queuing Telemetry Transport (MQTT) protocol to exchange messages between small built-in
computers, mobile devices, and sensors. Cloud-based database is used for storing data from the sensors and produces datasets for forecasting. A smart IoT network that is used by Nocheski et al. to simplify the control and management of a fish farm pond in remote areas, with the intention of getting it back to its natural state through the most productive means of remote monitoring using wireless networking systems such as cellular, LoRaWAN, WiFi or satellite connectivity [16]. The aim of this smart system is to reduce the environmental stress that affects the fish population in the fish farming pond.

One of the applications of IoT solution is already employed in shrimp pond research that installs multiple WSN nodes from one station to other locations [17]. The main structure is made up of sensor nodes, master, and web server modules. Data from the sensor node is transmitted to the master using the Xbee wireless transmitter (WSN) and then the master stores, displays, and transfers data to the server using Wireless Fidelity (Wifi). The data will be submitted to the website and distributed to a range of approved Android phones.

3. Research Methodology

3.1 IoT Solution

The simplified architecture of our current IoT solution and its corresponding electronic components is almost similar to the prior prototype (see reference [5]) as it is shown in Figure 1. The main microcontroller unit (MCU) is NodeMCU, which is an open-source firmware developed for a low-cost ESP8266 WiFi microchip that is mainly used to prototype IoT applications [18]. The Internet connectivity in the Wifi module allows users to share the data from ponds into a remote server and also mobile devices. The voltage between NodeMCU and Analog Digital Converter (ADC) with I2C is adjusted by a logic converter. Along with the temperature sensor, four more sensors are embedded in the ADC. Unlike the previous implementation, we replace the turbidity sensor by a salinity sensor because the majority of the fish ponds are aimed for the cultivation of striped snakehead fish that requires stricter monitoring of water salinity. However, all the embedded sensors in our IoT architecture can be replaced or added, depending on the needs.

![Figure 1. The main architecture of the pond IoT solution](image)

3.2 Mobile Application Development

To design the mobile application, we adopted the diagrams from Unified Modeling Language (UML). In particular, we used the use case and activity diagram to describe the application design. Use case diagram is used to describe the relationship between the users and the features that can be accessed by
the users. Meanwhile, the activity diagram is used to describe the workflow of the whole system, specifically the flow of activities among the users. Based on the design, the mobile application was developed by using Android Studio platform with React Native framework.

4. Result and Discussion

4.1 Pond IoT Implementation

The upgraded IoT solution has been assembled on a Printed Circuit Board (PCB) (see Figure 2) and implemented in all ponds in Serdang Bedagai, North Sumatera. Only the sensor probes that are situated within the pond while the PCB is put safely inside a closed box and it is placed on a pole nearby. Additionally, we also connect the main PCB with a display board to display real-time sensor measurements when the fish farmers check on the pond operation during site visits. Further, the IoT implementation also includes a solar panel installed on the top of the PCB box to produce a low-cost renewable energy source to power sensors and other electronic devices on the main PCB and the display board.

![Figure 2. The implemented IoT solution prototype (left) and the IoT solution embedded with a board display and a solar panel (right)](image)

4.2 Nusapond Mobile Application

In this work, an android-based platform called Nusapond has been developed to access the full features of control and monitoring of the smart pond IoT. In general, the application is capable of showing four main monitoring tasks for every pond: the real-time sensor measurements, the ongoing
fish production cycle, daily feeding records, and monitoring the health status of fish. The use case diagram depicted in Figure 3 summarizes the whole monitoring scheme that can be managed from Nusapond.

After successful login into the app, users are redirected to the main dashboard that contains the real-time measurements of water parameters of all ponds in one particular site (for example, Figure 4 (right) shows ponds’ conditions in Serdang Bedagai, North Sumatera. The dashboard can display two different types of pond based on their health status: normal pond (kolam normal) and ‘problematic’ pond (kolam kendala). All ponds will be automatically categorized ‘normal’ if one or more parameters are still within the allowed range of ideal conditions, if not they will be included as problematic ponds instead. This is demonstrated in Figure 4 (right) as the app notifies users that pond 2 (kolam 2) dan pond 5 (kolam 5) have an abnormal sensor measurement in turbidity and DO level, respectively, hence they are included in kolam kendala. This provides an automatic warning alert system to notify users if abnormal conditions are detected. We can manually adjust the allowed upper and lower ideal thresholds for each water parameter. In addition, users can manually move a normal pond into a problematic one if another issue arises in the pond (e.g. unhealthy fish stock, errors in IoT system, and more).

Figure 3. Use diagram case of pond management implemented in Nusapond app
Since the proposed Pond IoT solutions have been implemented in ponds located in Serdang Bedagai, the application allows the users to switch the real-time monitoring from one site into another pond site. Furthermore, we can add information about new ponds (e.g. pond size, type of cultivated fish, appointed person in charge (PIC), etc.) built in a particular site using a feature called “add new pond”. The activity diagram for this case is shown in Figure 5.

**Figure 5.** Activity diagram for changing the site location in Nusapond app
The starting period of the fish production cycle in a pond begins with stocking a certain number and weight of fish into the pond (initial fish stock). Following the end period of the cycle, the final fish stock is measured to compute pond production (a difference between the size of fish stock at the end period and the stock at the beginning of the period) as well as the survival rate and the mortality rate [19]. During an ongoing cycle, users can monitor the number of deaths and the Feed Conversion Ratio (FCR). FCR is the amount of feed necessary to gain one unit weight (kilogram) of fish [20]. This is an important quantity that needs to be optimally adjusted since underfeeding can result in loss of fish production due to lack of nutrition while overfeeding can be a waste of expensive feed as well as a potential cause of water pollution [21]. The application also includes a feature to manually start a new production cycle and abort the ongoing cycle.

The sensor measurement includes an option to display interactive graphs for each water parameters (see Figure 6 (right)). In addition, the application is equipped with a warning system that notifies users if the real-time water conditions measured from the sensors deviate from the allowed range of the critical pond conditions. The resulting monitoring datasets taking the form of historical data of all environment variables may provide a robust development of data-driven predictive modelling [22–26], for example via time series analysis [27], to evaluate water quality for the fish growth.

Further, the feeding records provide daily logs related to fish feeding and the type of food that can be added manually. Finally, users are also facilitated with a note regarding the health observation of the fish that includes the possible diseases (with pictures of the symptoms). The data collected from the health observations can be useful for the farmers to consult with a fish veterinarian for disease treatments as well as improving the overall health status of fish stock.

**Figure 6.** Two examples of pond management in Nusapond: fish production cycle (left) and the interactive graphs from sensor measurements (right)
5. Conclusion

In this paper, we have implemented an upgraded version of our smart pond IoT solution that integrates a mobile application along with the existing web application to provide remote monitoring of environment variables and efficient management for multiple fish ponds. The current IoT prototype is powered by solar energy from a solar panel and embeds a salinity sensor as well as a display board. Furthermore, the mobile application offers a wide range of tasks for maintaining efficient pond management, including real-time sensor measurements, fish production cycle, feeding management, and fish health monitoring. This allows farmers to monitor multiple ponds from a single mobile device. The whole IoT system is currently implemented in our ponds in Serdang Bedagai, North Sumatera. Finally, the future work mainly involves the development of the application that includes several new features allowing farmers to manage information about fish trade and supply fish for restaurants, hotels, or even traditional fish markets.

6. References

[1] FAO 2020 Fishery Statistical Collections: Global Aquaculture Production
[2] Oktopura A A D, Fauzi A, Sugema K and Mulyati H 2020 Aquaculture performance in Indonesia: economics and social perspectives IOP Conf. Ser. Earth Environ. Sci. 493 012003
[3] Simbeye D S and Yang S F 2014 Water quality monitoring and control for aquaculture based on wireless sensor networks J. Networks 9 840–9
[4] BPBAT Mandiangin 2014 Naskah Akademik Ikan Gabus Haruan (Channa striata Bloch 1793 Hasil Domestikasi. Kementerian Kelautan Perikanan, Mandiangin. 74 hlm
[5] Darmalim U, Darmalim F, Darmalim S, Hidayat A A, Budiarto A, Mahesworo B and Pardamean B 2020 IoT Solution for Intelligent Pond Monitoring IOP Conf. Ser. Earth Environ. Sci. 426
[6] Encinas C, Espinoza E R, Cortez J and Adolfo Espinoza 2017 Design and implementation of a distributed IoT system for the monitoring of water quality in aquaculture 2017 Wirel. Telecommun. Symp.
[7] Soeparno H, Perbangsa A S and Pardamean B 2018 Best Practices of Agricultural Information System in the Context of Knowledge and Innovation 2018 International Conference on Information Management and Technology (ICIMTech) pp 489–94
[8] Baurley J W, Perbangsa A S, Subagyo A and Pardamean B 2013 A Web Application and Database for Agriculture Genetic Diversity and Association Studies Int. J. Bio-Science Bio-Technology 5 33–42
[9] Pardamean B, Baurley J W, Perbangsa A S, Utami D, Rijzaani H and Satyawan D 2018 Information technology infrastructure for agriculture genotyping studies J. Inf. Process. Syst. 14 655–65
[10] Baurley J W, Budiarto A, Kacamarga M F and Pardamean B 2018 A Web Portal for Rice Crop Improvements Int. J. Web Portals 10 15–31
[11] Kacamarga M F, Pardamean B and Wijaya H 2015 Lightweight Virtualization in Cloud Computing for Research BT - Intelligence in the Era of Big Data ed R Intan, C-H Chi, H N Palit and L W Santoso (Berlin, Heidelberg: Springer Berlin Heidelberg) pp 439–45
[12] Anindito, Pardamean B, Christian R and Abbas B S 2013 Expert-system Based Medical Stroke Prevention J. Comput. Sci. 9
[13] Abdurrohman and Hadhiwibowo A 2019 Penerapan Konsep IoT dalam Budidaya Ikan Naratif (Jurnal Nas. Riset, Apl. Dan Tek. Inform. 1 1–6
[14] Idachaba F E, Olowoleni J O, Ibhaze A E and Oni O O 2017 IoT enabled real-time fishpond management system Lect. Notes Eng. Comput. Sci. 1 42–6
[15] Niswar M, Wainalang S, Ilham A A, Zainuddin Z, Fujaya Y, Muslimin Z, Paundu A W, Kashihara S and Fall D 2019 IoT-based water quality monitoring system for soft-shell crab farming Proc. - 2018 IEEE Int. Conf. Internet Things Intell. Syst. IOTAINS 2018 6–9
[16] Nocheski S and Naumoski A 2018 Water monitoring Iot system for fish farming ponds Int. Sci. J. “Industry 4.0” 79 77–9
[17] Maulana Y Y, Wiranto G and Kurniawan D 2016 Online Monitoring Kualitas Air pada Budidaya Udang Berbasis WSN dan IoT Online Water Quality Monitoring In Shrimp Aquaculture Based On WSN and IoT Inkom 10 81–6

[18] Anon ESP8266 NodeMCU

[19] FAO Monitoring, Record Keeping, Accounting, and Marketing in Aquaculture

[20] USAID 2011 Feed Conversion Ratio (FCR): USAID Harvest 1–2

[21] New M B 1987 Feed and Feeding of Fish and Shrimp (FAO and UNEP)

[22] Caraka R E, Supatmanto B D, Tahmid M, Soebagyo J, Mauludin M A, Iskandar A and Pardamean B 2018 Rainfall forecasting using PSPline and rice production with ocean-atmosphere interaction IOP Conf. Ser. Earth Environ. Sci. 195 12064

[23] Caraka R E, Tahmid M, Putra R M, Iskandar A, Mauludin M A, Hermansah, Goldameir N E, Rohayani H and Pardamean B 2018 Analysis of plant pattern using water balance and cimogram based on oldeman climate type IOP Conf. Ser. Earth Environ. Sci. 195 12001

[24] Caraka R E, Chen R C, Toharudin T, Pardamean B, Yasin H and Wu S H 2019 Prediction of Status Particulate Matter 2.5 Using State Markov Chain Stochastic Process and HYBRID VAR-NN-PSO IEEE Access 7 161654–65

[25] Caraka R E, Shohaimi S, Kurniawan I D, Herliansyah R, Budiarto A, Sari S P and Pardamean B 2018 Ecological Show Cave and Wild Cave: Negative Binomial Gllvm’s Arthropod Community Modelling Procedia Comput. Sci. 135 377–84

[26] Kurniawan I D, Soesilohadi R C H, Rahmadi C, Caraka R E and Pardamean B 2018 The difference on Arthropod communities’ structure within show caves and wild caves in Gunungsewu Karst area, Indonesia Ecol. Environ. Conserv. 24 72–81

[27] Caraka R E, Bakar S A, Pardamean B and Budiarto A 2017 Hybrid support vector regression in electric load during national holiday season 2017 International Conference on Innovative and Creative Information Technology (ICITech) pp 1–6