Design of Real-Time Aquarium Monitoring System for Endemic Fish on the Smartphone

Naufal Inas Fikri, Vito Louis Nathaniel, Muchamad Syahrul Gunawan, Tomy Abuzairi∗
Electrical Engineering, Department of Electrical Engineering, Faculty of Engineering, Universitas Indonesia, Depok, Indonesia

ABSTRACT

The high rate of decreasing population of endemic fish species is becoming more severe over time. Therefore, it needed an effort to bring back the stability of the number. One of the reasons for the decreasing population is the changing environment due to climate change and the difficulty of treatment for this species. This research aims to design an aquarium monitoring system for endemic fish. The main components for this system are microcontroller ESP32 DOIT, Temperature Sensors DS18B20, DF Robot Analog pH Sensors, ESP32 Cam, UV Lamp, and Blynk server. The experiment was conducted by monitoring the aquarium environment using sensors and comparing it with the reference sensors. With a monitoring system, we can find out whether the current condition of the aquarium is in accordance with the fish's living environment or not. The monitoring results show that the average error for temperature is 0.14% and for pH is 0.67%. These results indicate that the prototype sensors are linear with reference sensors. Besides that, a real-time monitoring system is easy to use and more attractive because of smartphone utilization to monitor fish with a camera and lamp.

This work is licensed under a Creative Commons Attribution-Share Alike 4.0

Tomy Abuzairi,
Electrical Engineering, Department of Electrical Engineering, Faculty of Engineering, Universitas Indonesia, Indonesia
Email: tomy.abuzairi@ui.ac.id

1. INTRODUCTION

Indonesia is an archipelagic country with a tropical climate rich in biodiversity or commonly called "Mega-biodiversity" [1][2]. As an archipelagic country, Indonesia covers around 5,193,250 million km² area, where two-thirds of Indonesia’s territory is a water area of 3.25 million km² [3][4]. The area of water that is larger than the mainland makes Indonesia rich in fish species. There are 4,782 fish species recorded in Indonesia, and about 130 are endemic species [5]. Endemic species are species that grow naturally in only one geographic area. Naturally, The factors that cause the endemism of animals are temperature, humidity, and wind [6].

However, this diversity is not in line with public awareness to maintain and preserve the diversity of endemic fauna. It is characterized by being very rare and difficult to find in its natural habitat [7]. This problem has occurred for a long time but has not been resolved until now. Moreover, water temperature has an important role in fish development activities. Rapid temperature increases are known to cause acute stress responses and expose fish to disease. In addition, highly fluctuated temperatures can cause fish death [8][9]. In addition, a good pH content for fish waters generally ranges from 5-9. Inappropriate pH content can cause fish vulnerability to parasites, growth to slow down, cause physiological disturbances in fish, and decrease the survival of fish [10][11].

The Internet of Things (IoT) refers to a network to connect anything with the Internet. Internet of Things enables one device to control and monitor other devices in the same network [12][13]. Currently, the development of IoT is very rapid. It has allowed for various possibilities in technological advancements for different aspects of life [14][15]. With the condition of endemic fish habitat becoming concerning and overexploited increasingly, the application of IoT-based technology that is integrated with sensors and
Design of Real-Time Aquarium Monitoring System for Endemic Fish on the Smartphone (Naufal Inas Fikri)

Actuators make Ex-Situ conservation more and more well-monitored and controlled. However, the current smart aquarium system can only monitor the quality of the water in the aquarium without displaying the visual state of the aquarium in real-time [16]. Table 1 shows a comparison of the features possessed by the related works. This study aims to design an aquarium system to monitor (temperature and pH) and display the aquarium's condition using a camera in real-time. The research contribution is to apply technology for monitoring in Ex-situ conservation.

| References | pH | Temperature | TDS | Turbidity | Camera | Lamp |
|------------|----|-------------|-----|-----------|--------|------|
| [17]       | ✓  | ✓           | -   | -         | -      | -    |
| [18]       | ✓  | -           | ✓   | -         | -      | -    |
| [19]       | ✓  | ✓           | -   | -         | -      | -    |
| [20]       | ✓  | ✓           | ✓   | ✓         | -      | -    |
| [21]       | -  | ✓           | -   | -         | -      | -    |
| This work  | ✓  | ✓           | -   | -         | ✓      | ✓    |

2. RESEARCH METHOD

Fig. 1 and Fig. 2 show the design and block diagram of the prototype. The main components for this system are microcontroller ESP32 DOIT, Temperature Sensors DS18B20, DF Robot Analog pH Sensors, ESP32 Cam, UV Lamp, and Blynk server.

Fig. 1. Design of prototype.

Fig. 2. Prototype block diagram.

PCB design and wiring tool are shown in Fig. 3. This prototype uses the ESP32 Development board as the main microcontroller, which is powered by a dual-core Tensilica Xtensa LX6 microprocessor [22][23].
Its minimalist design but equipped with a WiFi module makes the ESP32 a good microcontroller for IoT development. The DS18B20 is a waterproof temperature sensor used to measure liquids, soils, or solutions. The temperature sensor DS18B20 has a temperature measurement range from -55°C to 125°C and uses a 3.0–5.0 V supply for its operation [24][25]. In reading the aquarium water temperature, we use the DS18B20 sensor, changing the temperature value to voltage. The pH sensor used in this system is the DFRobot sensor kit which has a measuring range of 0-14 with accuracy ± 0.1 and response time ≤ 1 min [26]. This sensor works with a working voltage of 5V, so it is easy to integrate with a microcontroller [27]. The camera functions as a monitoring tool for fish and aquarium conditions. The camera will be connected to the IoT server so that users can see the condition of the aquarium from anywhere. In this prototype, we use the ESP32 Cam as a camera module which has a small size board with a footprint of 27x40.5x4.5 millimeters. The ESP32-Cam uses an OV2640 camera module. It can operate with a maximum resolution of 1600x1200 pixels at fifteen frames per second [28]. UV lamps are used to reduce the viability of the fish pathogenic bacterium [29].

The smartphone application for this prototype is utilized the Blynk platform. Blynk is an IoT platform that enables the development and implementation of smart IoT devices with ease and speed. With Blynk, all the sensor data can be observed in real-time easily from our smartphones, and the user can also give orders to the prototype [30][31]. This can be facilitated because Blynk provides cloud services to exchange information between tools and users. In addition, the application also has an additional feature that is a reminder that will notify users if the aquarium conditions are outside normal limits. Users can enter the limits for normal conditions of temperature and pH in the application. So, if the condition of the aquarium water is not between these normal limits, then the application in the smartphone will send a notification to the user's smartphone.

3. RESULTS AND DISCUSSION
Data collection using the prototype is shown in Table 2 for temperature measurement and Table 3 for pH measurement. The prototype was tested in an aquarium with dimensions of 90x40x40 cm³ filled with 77 liters of water, as shown in Fig. 4. The fish used as the subject for this prototype is the Sepat Mutiara (Trichopodus leeri).

![Fig. 3. Schematic circuit of the prototype.](image)

![Fig. 4. View of the prototype.](image)
Table 2 shows the average error data from the temperature test. Error data is obtained by comparing the temperature read by the DS18B20 sensor and the reference temperature every 5 minutes, five times each day, for three days. From the test, the average error for temperature is 0.14%. The linear temperature relationship of the prototype with the reference is shown in Fig. 5.

| Day | Time Sampling | Prototype temperature (°C) | Reference Temperature (°C) | Error rate |
|-----|---------------|-----------------------------|-----------------------------|------------|
| 1   | 1             | 29.94                       | 29.9                        | 0.13%      |
|     | 2             | 29.94                       | 29.9                        | 0.13%      |
|     | 3             | 29.94                       | 29.9                        | 0.13%      |
|     | 4             | 29.94                       | 29.9                        | 0.13%      |
|     | 5             | 29.94                       | 29.9                        | 0.13%      |
| Mean 1 |               |                             |                             | 0.13%      |
| 2   | 1             | 29.95                       | 29.9                        | 0.17%      |
|     | 2             | 29.95                       | 29.9                        | 0.17%      |
|     | 3             | 29.95                       | 29.9                        | 0.17%      |
|     | 4             | 29.95                       | 29.9                        | 0.17%      |
|     | 5             | 29.95                       | 29.9                        | 0.17%      |
| Mean 2 |               |                             |                             | 0.17%      |
| 3   | 1             | 30.04                       | 30.0                        | 0.13%      |
|     | 2             | 30.04                       | 30.0                        | 0.13%      |
|     | 3             | 30.04                       | 30.0                        | 0.13%      |
|     | 4             | 30.04                       | 30.0                        | 0.13%      |
|     | 5             | 30.04                       | 30.0                        | 0.13%      |
| Mean 3 |               |                             |                             | 0.13%      |
| Average |               |                             |                             | 0.14%      |

Fig. 5. Comparison temperature between prototype and reference.

Table 3 shows the average error data from the pH test. The error data is obtained by comparing the temperature read by the pH analog sensor and the reference pH in 5-minute intervals, five times each day, for three days. From the test, the average error for pH is 0.67%. The pH linear relationship of the prototype with the reference is shown in Fig. 6.
Table 3. Data accuracy measurements of pH.

| Day | Time Sampling | Prototype pH | Reference pH | Error rate |
|-----|---------------|--------------|--------------|------------|
| 1   | 1             | 7.89         | 7.8          | 1.15%      |
|     | 2             | 7.93         | 7.9          | 0.38%      |
|     | 3             | 8.02         | 7.9          | 1.52%      |
|     | 4             | 7.83         | 7.9          | 0.89%      |
|     | 5             | 7.87         | 7.9          | 0.38%      |
| Mean 1 |               |              |              | 0.86%      |
| 2   | 1             | 7.92         | 7.9          | 0.25%      |
|     | 2             | 7.90         | 7.9          | 0%         |
|     | 3             | 7.97         | 7.9          | 0.89%      |
|     | 4             | 7.94         | 7.9          | 0.51%      |
|     | 5             | 7.87         | 7.8          | 0.9%       |
| Mean 2 |               |              |              | 0.51%      |
| 3   | 1             | 7.98         | 8.0          | 0.25%      |
|     | 2             | 8.12         | 8.0          | 1.5%       |
|     | 3             | 8.05         | 8.0          | 0.625%     |
|     | 4             | 7.97         | 8.0          | 0.375%     |
|     | 5             | 8.03         | 8.0          | 0.375%     |
| Mean 3 |               |              |              | 0.63%      |
| Average |            |              |              | 0.67%      |

In addition to obtaining the pH and temperature data, we also tested other features of the prototype, such as a camera, UV lamp, and the use of a web server for setting Wi-Fi credentials. Based on the experiment, we found that the best resolution of the ESP32-Cam for monitoring the aquarium of 90x40x40 cm³ is 640x480 pixels. This resolution will have a good image quality with a short rendering time. At the same time, the use of UV lamps in our aquarium is very useful for lighting and monitoring the aquarium, as shown in Fig. 7. Besides that, UV lamps also can inhibit the growth of bacteria.
4. CONCLUSION

A real-time aquarium monitoring that can monitor fish photos, temperature and pH conditions on the smartphone has been successfully designed. The monitoring results on this prototype were tested in 5-minute intervals with five sampling times. The average error for temperature is 0.14% and for pH is 0.67%. These results indicate that the measurements made by the prototype are linear with reference data. In addition, this prototype can be further developed by adding features for temperature and pH control.

Acknowledgments

This work has been supported by Pekan Kreativitas Mahasiswa 2021 from the Ministry of Education, Culture, Research, and Technology Republic of Indonesia.
REFERENCES

[1] Sukardiyo and D. Rosana, “Megabiodiversity Utilization through Integrated Learning Model of Natural Sciences with Development of Innertdepend Strategies in Indonesian Border Areas,” in IOP Conference Series: Journal of Physics, 2019. https://doi.org/10.1088/1742-6596/1233/1/012099

[2] Y. Timorya, A. Abdullah, A. S. Batubara and Z. A. Muchlisin, "Conservation and economic status fishes in the Krueng Sabee River, Aceh Jaya District, Aceh Province, Indonesia," in IOP Conference Series: Earth and Environmental Science, vol. 216, no. 1, p. 012044, 2018. https://doi.org/10.1088/1755-1315/216/1/012044

[3] M. Nurnuffiada, G. H. Wangrimen, R. Reinalta and K. Leonardi, "Rendang: The treasure of Minangkabau," Journal of Ethnic Foods, vol. 4, no. 4, pp. 232-235, 2017. https://doi.org/10.1016/j.jef.2017.10.005

[4] D. O. Mahara and M. H. S. Kurniawan, "Survival Analysis Based on Average Response Time of Maritime Search and Rescue (SAR) Incidents in 2019 Using Kaplan-Meier Method and Log-Rank Test," ENSTHUISIATIC: International Journal of Applied Statistics and Data Science, vol. 1, no. 1, pp. 7-12, 2021. https://doi.org/10.20885/enthusiastic.vol1.is1.art2

[5] G. S. Haryani, "Sustainable use and conservation of inland water ecosystem in Indonesia: Challenge for fisheries management in lake and river ecossystem," in IOP Conference Series: Earth and Environmental Science, vol. 789, No. 1, p. 012023, 2021. https://doi.org/10.1088/1755-1315/789/1/012023

[6] O. Oyebanji, G. Salako, L. Nneji, S. Odadipo, K. Bolarinwa, E. Chakwuna, A. Ayoola, T. Olagunju, D. Igho and L. Nneji, "Impact of climate change on the spatial distribution of endemic legume species of the Guineo-Congolian forest area, Africa," Ecological Indicators, vol. 122, 2021. https://doi.org/10.1016/j.ecolind.2020.107282

[7] H. Yılmaz, O. Y. Yılmaz and Y. F. Akyüz, "Determining the factors affecting the distribution of Muscari latifolium, an endemic plant of Turkey, and a mapping species distribution model," Ecological Indicators, vol. 7, no. 4, 2014. https://doi.org/10.1016/j.ecolind.2013.2766

[8] S. Alfonso, M. Gesto and B. Sadoul, "Temperature increase and its effects on fish stress physiology in the context of global warming," Journal of Fish Biology, vol. 98, pp. 1496-1508, 2020. https://doi.org/10.1111/jfb.14599

[9] S. B. Bedassa, "Identification of possible causes of fish death in Lake "Lake Kabo"," International Journal of Fisheries and Aquaculture, vol. 11, no. 2, pp. 29-36, 2019. https://doi.org/10.5897/IJFA2018.0721

[10] K. Marimuthu, H. Palaniandy and Z. A. Muchlisin, "Effect of different water pH on hatching and survival rates of African catfish Clarias gariepinus (Pisces: Clariidae)," Aeob Journal of Animal Science, vol. 4, no. 2, pp. 80-88, 2019. https://doi.org/10.13170/ajas.4.2.13574

[11] V. C. Mota, J. Hop, L. A. Sampaio, L. T. N. Heinsbroek, M. C. Verdegem, E. H. Eding and J. A. J. Verreth, "The effect of low pH on physiology, stress status and growth performance of turbot (Psetta maxima L.) cultured in recirculating aquaculture systems," Aquaculture Research, vol. 49, no. 10, pp. 3456-3467, 2018. https://doi.org/10.1111/are.13812

[12] K. K. Patel, S. M. Patel, P. G. Scholar and C. Salazar, "Internet of Things-IOT: Definition, Characteristics, Architecture, Enabling Technologies, Application & Future Challenges," International Journal of Engineering Science and Computing, vol. 6, no. 5, 2016.

[13] A. Khanna and S. Kaur, "Internet of Things (IoT), Applications and Challenges: A Comprehensive Review," Wireless Personal Communications, vol. 114, pp. 1687–1762, 2020. https://doi.org/10.1007/s11277-020-07446-4

[14] S. Kumar, P. Tiwari and M. Zymbler, "Internet of Things is a revolutionary approach for future technology enhancement: a review," Journal of Big Data, vol. 6, no. 1, 2019. https://doi.org/10.1186/s40537-019-0268-2

[15] S. Nizićetić, P. Šolić, D. L. Čakala, D. Popić, V. C. Mota, J. Hop, L. A. Sampaio, L. T. N. Heinsbroek, M. C. Verdegem, E. H. Eding and J. A. J. Verreth, "Effect of low pH on the growth and survival performance of turbot (Psetta maxima L.) cultured in recirculating aquaculture systems," Aquaculture Research, vol. 49, no. 10, pp. 3456-3467, 2018. https://doi.org/10.1111/are.13812

[16] R. H. Hardyanto, A. Asmara and P. W. Ciptadi, "Smart Aquarium Based On Internet of Things," Journal of Business and Information Systems, vol. 1, no. 1, 2019. https://doi.org/10.36067/jbis.v1i1.12

[17] N. K. Saith, I. Hasan and N. I. Abdulkhalèq, "Design and implementation of a smart monitoring system for water quality of fish farms," Indonesian Journal of Electrical Engineering and Computer Science, vol. 14, no. 1, pp. 44-50, 2019. https://doi.org/10.11591/ijeecs.v14i1.pp44-50

[18] P. Periyadi, G. I. Hapsari, Z. Wakid and S. Mudopar, "IoT-based puppy fish farming monitoring," TELKOMNIKA Telecommunication, Computing, Electronics and Control, vol. 18, no. 3, pp. 1538-1545, 2020. https://doi.org/10.12928/telekomnika.v18i3.14850

[19] M. M. Khan, "An IoT Based Smart Water Monitoring System for Fish Farming in Bangladesh," in 5th International Electronic Conference on Water Sciences session New sensors, New Methods and Technologies, New Approaches, 2020. https://doi.org/10.3390/ECWSS.2020.08044

[20] O. A. Nasir and S. Muntazah, "IoT-Based Monitoring of Aquaculture System," MATER: International Journal of Science and Technology, vol. 6, no. 1, pp. 40-44, 2020. https://doi.org/10.20319/mijst.2020.61.113137

[21] P. B. B. Jr. and O. E. Llantos, "Design and Implementation of Real-Time Mobile-based Water," in 1th Information Systems International Conference 2017, Bali, 2017. https://doi.org/10.20319/mijst.2020.61.113137

[22] G. Fabregat, J. A. Belloch, J. M. Badía and M. Cobos, "Design and Implementation of Acoustic Source Localization on a Low-Cost IoT Edge Platform," IEEE Transactions on Circuits and Systems—II: Express Briefs, vol. 67, no. 12, pp. 3547-3551, 2020. https://doi.org/10.1109/TCSII.2020.2986296

[23] I. Koenen, V. Klar and R. Viitala, "IoT connected device for vibration analysis and measurement," HardwareX, vol. 7, 2020. https://doi.org/10.1016/j.hx.2020.e00109

[24] S. V. Gaikwad, A. D. Vibhute, K. V. Kafe and S. C. Mehrotra, "An innovative IoT based system for precision farming," Computers and Electronics in Agriculture, vol. 187, 2021. https://doi.org/10.1016/j.compag.2021.106291
Design of Real-Time Aquarium Monitoring System for Endemic Fish on the Smartphone (Naufal Inas Fikri)

[25] N. Kothari, J. Shreemali, P. Chakrabarti and S. Poddar, "Design and implementation of IoT sensor based drinking water quality measurement system," *Materials Today: Proceedings*, 2021. https://doi.org/10.1016/j.matpr.2020.12.1142

[26] H. Helmy, A. Nursyahid, T. A. Setyawan and A. Hasan, "Nutrient Film Technique (NFT) Hydroponic Monitoring System,” *JAICT, Journal of Applied Information and Communication Technologies*, vol. 1, no. 1, 2016. https://doi.org/10.1109/COMNETSAT.2017.8263577

[27] D. Petrov, K.-F. Taron, U. Hilleringmann and T.-H. Joubert, "Low-cost Sensor System for on-the-field Water Quality Analysis," in *2021 Smart Systems Integration (SSI)*, 2021, pp. 1-4. https://doi.org/10.1109/SSI52265.2021.9466956

[28] S. Nuanmeesri, L. Poomhiran and P. Kadmateekarun, "Face mask detection and warning system for preventing respiratory infection using the internet of things,” *COMPUSOFT, An international journal of advanced computer technology*, vol. 9, no. 9, pp. 3810-3816, 2020. https://ijact.in/index.php/ijact/article/view/1205

[29] H. Liltved and B. Landfald, "Effects of high intensity light on ultraviolet-irradiated and non-irradiated fish pathogenic bacteria," *Water Research*, vol. 34, no. 2, pp. 481-486, 2000. https://doi.org/10.1016/S0043-1354(99)00159-1

[30] M. S. Chawla, D. Prakash and S. Jindal, "Design of system for measuring air properties for help during COVID-19 scenario," *Materials Today: Proceedings*, vol. 45, no. 6, pp. 4472-4476, 2021. https://doi.org/10.1016/j.matpr.2020.12.987

[31] W. A. Jabbar, C. W. Wei, N. A. A. M. Azmi and N. A. Haironnazli, "An IoT Raspberry Pi-based parking management system for smart campus,” *Internet of Things*, vol. 14, 2021. https://doi.org/10.1016/j.iot.2021.100387

BIOGRAPHY OF AUTHORS

**Naufal Inas Fikri** is currently pursuing a bachelor's degree in electrical engineering at, Department of Electrical Engineering, Faculty of Engineering, Universitas Indonesia. Email: naufal.inas@ui.ac.id

**Vito Louis Nathaniel** is currently pursuing a bachelor's degree in electrical engineering at, Department of Electrical Engineering, Faculty of Engineering, Universitas Indonesia. Email: vito.louis@ui.ac.id

**Muchamad Syahrul Gunawan** is currently pursuing a bachelor's degree in electrical engineering at, Department of Electrical Engineering, Faculty of Engineering, Universitas Indonesia. Email: muchamad.syahrul@ui.ac.id

**Tomy Abuzairi** received the B. Eng degree in electrical engineering from the Department of Electrical Engineering, Universitas Indonesia, in 2009, the M.Sc degree (double degree program) in optoelectronic engineering and electrical engineering from National Taiwan University of Science and Technology, and Universitas Indonesia, in 2012, the Ph.D. degree (double degree program) in a graduate school of science and technology, and electrical engineering from Shizuoka University and Universitas Indonesia, in 2016. He joined the Department of Electrical Engineering, Universitas Indonesia, in 2017, where he is currently an Assistant Professor. He has authored or co-authored over 40 articles published in refereed journals and conferences. He holds several patents for instrumentation and sensor. His research interests include biomedical instrumentations, optoelectronic, plasma technology, nanotechnology, and sensor. Email: tomy.abuzairi@ui.ac.id