ELE3305

Design Report

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# Executive Summary

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# Application Scenario

Aquaponics is defined as a closed system where fish and plants survive and grow together by providing each other with nutrients. In this system, rather than filtering out waste from the tanks, the waste from fish is consumed by bacteria and converted into nitrates which plants use for nourishment [1] [2]. The thriving plants then release oxygen into the water which circulates back to the fish. In this system, the delicate balance of water pH, temperature and oxygen levels are vital for a happy ecosystem [3], and so requires constant monitoring to ensure fish and plants are obtaining adequate nutrients and not stressed out.

Implementing automated monitoring and maintenance to the aquaponics system using Internet of Things (IoT) will take the strain off the owner of the aquaponics system to ensure all these elements are measured and addressed in a timely manner, reducing the risk of plant and fish illness or death caused by lack of supervision [1] [4].

# Specifications

## Sensors

The details of the sensors required to monitor the aquaponics system include the following:

Table 1: Sensor information

|  |  |  |  |
| --- | --- | --- | --- |
| **What is Measured** | **Ideal Range** | **Units** | **Recommended Sensor** |
| Dissolved Oxygen (DO) | 5-8 | mg/L | Atlas DO probe |
| pH | 6.5-8 | - | DFROBOT-SKU:SEN0169 |
| Water Temperature | 18-30 | °C | DFROBOT-DS18B20 |

The information obtained from these sensors is sent as a message to an MQTT broker, Mosquitto. The broker then sends the message through the local network to the nodes: Node-Red, OpenPLC and a web-based human machine interface (HMI). These nodes are installed on a Raspberry Pi.

## Node-Red

Node-Red is used to implement the IoT network. This receives the information from the sensors and creates flows for the decoding and scaling the information to be sent to the PLC. This also provides the interface for the user to interact with the system where they can view alerts and controls, as mentioned below under HMI.

## OpenPLC

OpenPLC is used to implement automated control to the aquaponics system, which is laid out in Table 2. If any values outside of the ideal range mentioned in Table 1 are detected, OpenPLC will activate an action to maintain balance of the three aquarium factors.

It should be noted that the provided actions are not exclusive (as temperature, DO and pH can directly affect each other), but are the only ones provided to maintain simplicity for the conceptual design of the system. It is assumed in a well-balanced system that the pH level will be self-maintained and should not fall outside the ideal range, but if it does it requires direct intervention from the user due to complex associations to other variables, so OpenPLC will only send out an alert.

For DO and water temperature, the pumps will activate automatically but the design will also allow the user to turn on or off the air pump and water pump as needed.

Table 2: Control of sensor readings

|  |  |  |
| --- | --- | --- |
| **Sensor** | **Problem** | **Required Action** |
| DO | < 5 mg/L | Turn on air pump |
| > 8 mg/L | Turn off air pump |
| pH | < 6.5 | Notify user |
| > 8 | Notify user |
| Water Temp | < 18 °C | Turn on heating system |
| > 30 °C | Turn on water pump to increase flow |

## HMI

The human-machine interface (HMI) is the final node which the user can access using a browser in kiosk mode. This will only allow access to Node-Red’s user interface (UI) and will display information on the pH, DO and water temperature of the tanks. This can be implemented on any tablet device for convenience so the user can easily transport it while checking the tanks of the aquaponics system.

## Power Supply

It is considered that the system can be connected to mains power or utilise solar and incorporate battery back up to ensure upkeep of the tanks in the event of power loss. The simplicity of this aquaponics system can be scaled up to meet larger demands including aquariums and farming [2].

# Overview of System

Documentation of the existing system including an overview of the relevant protocols used in the context of the project and an evaluation of why they are appropriate for the application or why other protocols would be more suitable.

Modbus is used for communication between OpenPLC and the control devices of the aquaponics system.

# Data Encoding/Scaling

Detail the data encoding and scaling across the various transmission channels in the system.

Scaling for pH: whole range needs to fit into 0-14.

Scaling for water temperature: range needs to fit into -55 to 125 C.

Scaling for DO: range needs to fit into 0-100 mg/L (https://atlas-scientific.com/probes/dissolved-oxygen-probe/)

# ICT security risks

A discussion of potential ICT security risks in the system and potential ways to alleviate those risks.

Potential unauthorized access to HMI.

Access to Node-red and the flows are changed or information obtained.

No issue with confidential information being obtained via the sensors, however login information could be at risk in the local network.

# Conceptualisation

Conceptualisation and documentation of the system and code to achieve the functionality.

This includes the local network configuration. This needs to include details such as the assumptions you have made, function definitions and shortcomings of the implementation and potential improvements. This section should be supported by block diagrams, flow charts etc as appropriate.

# References

[1] M.M.M. Mahmoud, R. Darwish and A.M. Bassiuny, “Development of an economic smart aquaponic system based on IoT,” *J. Eng. Res.*, Aug 2023, doi: https://doi.org/10.1016/j.jer.2023.08.024.

[2] M. F. Taha et al., “Recent Advances of Smart Systems and Internet of Things (IoT) for Aquaponics Automation: A Comprehensive Overview,” *Chemosensors*, vol. 10, no. 8, Aug 2022, doi: https://doi.org/10.3390/chemosensors10080303

[3] S. Fu, W. Xing, J. Wu, J. Chen and S. Liu, “Research and design of an intelligent fish tank system,” *PLoS ONE*, vol. 18, no. 5, May 2023, doi: <https://doi.org/10.1371/journal.pone.0285105>.

[4] F. A. Z. Shaikh and U. Bhaskarwar, “Smart Aquarium using IoT,” *Int. J. Res. Appl. Sci. Eng. Tech. (IJRASET),* vol. 10, no. 3, Mar 2022. [Online]. Available:<https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4089695>

[5] C.-H. Chiung, Y.-C. W, J.-X. Zhang and Y.-H. Chen, “IoT-Based Fish Farm Water Quality Monitoring System,” *Sensors,* vol. 22, no. 17, Sep 2022, doi: https://doi.org/10.3390/s22176700.