THE UNIVERSITY OF BRITISH COLUMBIA

IoT Monitoring of Aquaponic and Hydroponic Food Production

Requirements

UBC Electrical and Computer Engineering Capstone 121

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for

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April 13, 2021

Revision History

Date	**Author**	**Sections**	**Change**
2020-10-05	JL	1.0 - 2.0	Creation of document skeleton
2020-10-30	CB	1.0 - 5.0	Added system overview and skeleton of subsystem sections
2020-10-30	CB	1.0 - 5.0	Edited Document with feedback from Dr. Lusina and Clients
2020-11-28	JL	1.0 - 5.0	Major revisions to all sections for design review 1.
2021-01-15	MD	1.0 - 5.0	Major revisions to all sections for design review 2.
2021-02-19	JL	4.1, 4.2	Increase specificity and measurability of functional and non-functional requirements. Included NF_x and F_x labels for clarity, instead of numbered lists

Contents

1 Context

In this section, an introduction of our clients and their goals is given. Our clients are Bernhard Nimmervoll of the University of British Columbia (UBC) Mechanical Engineering Department, and Nelly Leo of the UBC Social Ecological Economic Development Studies (SEEDS) Program.

Secondly, this section includes a description of aquaponics and hydroponics. Briefly, aquaponics and hydroponics are food production methods known for being more sustainable than traditional food productions practices.

Finally, a description of the problem this project aims to solve will be given. Overall, this project aims to make aquaponics and hydroponics easier to maintain and monitor. This will, in turn, serve to promote aquaponics and hydroponics as sustainable methods of food production.

1.1 Client Introduction

The primary client of this project is Bernhard Nimmervoll, a Technician for the UBC Mechanical Engineering Department. Bernhard is a passionate advocate of sustainabililty initiatives, including being a hobbyist aquaponics grower in his spare time. Bernhard introduced this project as a way to promote aquaponics and hydroponics as sustainable food production methods, and as a way to combat food insecurity.

Bernhard has partnered with a UBC organization called the Social Ecological Economic Development Studies (SEEDS) Sustainability program. The SEEDS program developed out of UBC's commitment to being a global leader in integrated sustainability [1]. As such, SEEDS is an organization whose aims are to advance the well-being of the environment, local biodiversity, food systems, responsible consumption and community inclusion. They are pursuing these aims by supporting student-led research and development about climate friendly food systems, urban food production for community resilience, biodiverse food systems, zero-waste, and food justice and sovereignty. This project is one of many such UBC SEEDS projects.

UBC SEEDS' has five main research goals, which are shown in Figure 1. The research goal, 'Enable the great food transformation', is the primary focus of our project. This goal is typically pursued by researching food security and sustainability, implementing policies and plans, and participating in education, engagement, and demonstration. In our case, our project will contribute to this goal by advancing technology related to sustainable food growth using aquaponics and hydroponics.

Figure 1: UBC SEEDS big five research priorities [2]

Nelly Leo is the UBC SEEDS coordinator overseeing this project. She is responsible for ensuring that this project meets overall SEEDS objectives.

1.2 Hydroponics and Aquaponics

Hydroponics is a method of agriculture where plants are grown in a nutrient-rich aqueous solution. Nutrients in hydroponics are inputted by the grower to nourish plants. This contrasts traditional forms of agriculture, where plants are grown in soil.

Aquaponics is very similar to hydroponics. In aquaponics, plants are also grown in an aqueous solution, however plants recieve nutrients in a different manner. Instead of growers inputting nutrients, plants recieve nutrients from fish waste. To make this possible, fish are raised in water tanks that the plants are grown in. Aquaponics recieves its name because of this, by being a mixture of aquaculture and hydroponics. A simplified diagram of aquaponics is show in Figure 2.

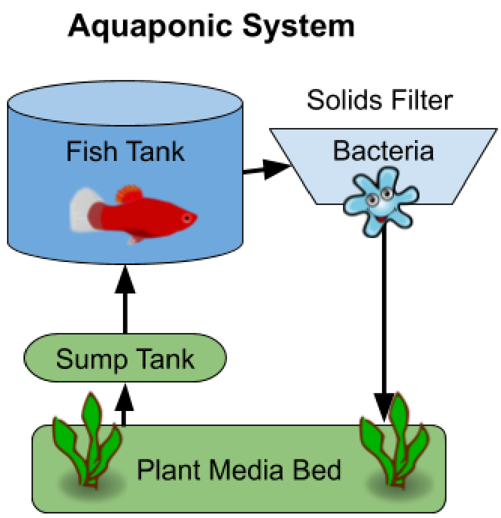

Figure 2: A diagram of a basic aquaponics system

Both hydroponics and aquaponics are being developed as more sustainable approaches to agriculture than traditional methods for the following reasons [3]:

1. Higher crop production per unit area;
2. Faster plant growth;
3. Lower water usage;
4. Lower susceptibility to pests if grown indoors.

For aquaponics, there are also the following additional benefits [4][5]:

1. Fish and plants form a circular, self-sustaining ecosystem;
2. Fish food is the only input needed;
3. Fish as well as plants can be harvested for food.

For the benefits listed above, our clients, Bernhard Nimmervoll and UBC SEEDS, are interested in improving and advocating for these more sustainable agricultural methods.

1.3 Problem

Both aquaponic and hydroponic systems need to be carefully monitored. Plants require that the aqueous solutions they are planted in have all neccesary nutrients. They also require other environmental variables to be monitored, including solution pH, light intensity, humidity, and more. In addition, aquaponic systems are even more difficult systems to maintain due to their complex multi-species dynamics. Systems need to be balanced such that fish, bacteria, and plants can all thrive.

With this system complexity, hydroponics and aquaponics require frequent supervision and maintenance by a knowledgeable operator. This adds significant cost and labor for aquaponics and hydroponics growers. This can be discouraging for small scale and hobbyist aquaponic or growers who do not currently have access to an affordable, automated monitoring and control system.

2 Domain

This project is within the domain of aquaponics and hydroponics monitoring and control systems typically built by hobbyists and small companies. These are small-scale monitoring and control systems usually designed for and installed on a single aquaponics or hydroponics system. They are also usually open-source and non-proprietary. The vast majority of these systems monitor their systems using internet connectivity, making them categorizable as small-scale internet of things (IoT) projects.

Many of the previous implementations of systems of this type are simplistic and designed for single systems without much forethought for future development [7][8]. Some of the systems have been designed with future improvements, ease of setup, cost, and efficiency in mind [9][10]. An example of such a system is shown below in Figure 3. This system is quite expensive for an monitoring system that is built using off the self components, costing around $850. The system also seems to have limited external monitoring capabilities and no licensing for open source although they claim to be an open source project. As well, the monitoring system doesn't record any data and does not seem to have any response system in place in case of power failure.

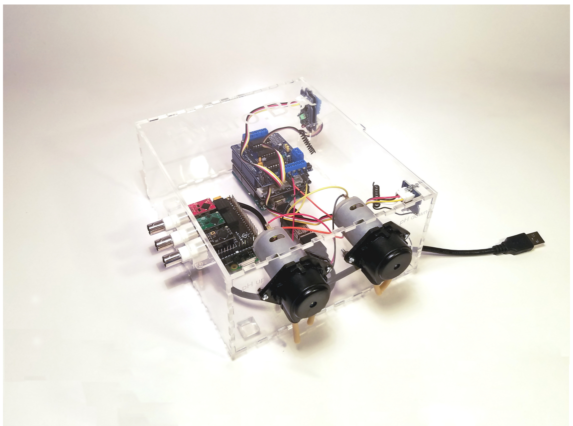

Figure 3: An example of an existing system called HydroBot [10]

3 Goal

The goal of this project is to develop a user-friendly, no-technical-expertise-needed solution for monitoring and control of hydroponic or aquaponic systems. This system should utilize open-source and low cost technologies wherever possible to minimize barriers to replication and access. In terms of scope, our project serves to deliver a working prototype of such a system which is installed on an existing hydroponic or aquaponic system.

When completed, this project will help solve the problem of hobbyist and aquaponic growers monitoring and maintaining their systems. It will help reduce cost, time, and effort associated with aquaponics and hydroponic systems; and help reduce system failures resulting in production losses.

In addition to these benefits, this project will also contribute towards larger goals including increasing food systems sustainability, reducing food insecurity, and increasing sustainability awareness. First of all, by making hydroponics and aquaponics systems easier to develop and maintain, this may encourage more growers to use these methods. This, in turn, can promote food systems sustainabililty as aquaponics and hydroponics have advantages over traditional growing methods.

In terms of food insecurity, this project may be included in future on-campus aquaponics or hydroponics growing systems. For example, a physical 'FoodHub' is being envisioned UBC Okanagan (UBCO) campus [6]. This 'FoodHub' may provide affordable, local, organic vegetables and fish to UBCO community members as an effort to reduce student food insecurity. This Food Hub is being planned to include an aquaponic system of both functional, research, and educational value. The product of this project could be a helpful addition to monitor such a system, and could therefore contribute to broader issues including reducing food insecurity.

4 Requirements

In order to meet the goals in section 3, our team has generated functional and non-functional requirements for this project.

4.1 Functional Requirements

This project must perform the following functions:

F_1 **Display measurements of critical system variables in hydroponic or aquaponic systems.** For the scope of our project, critical system variables include and are limited to pH, water level, water leakage, and water temperature. All displayed measurements must be updated at a minimum of every five minutes.

F_2 **Store and display past measurements of critical system variables so hydroponic or aquaponic growers can analyze system trends.** The system must be capable of storing and displaying at least the past 3 months worth of measurements.

F_3 **Send alerts to growers within 1 minute of a detecting that a critical system variable is outside of a normal range.** Growers will specify normal ranges for each of the critical system variables.

F_4 **Adjust pH level and water level automatically such that they always stay within a pre-defined range.** This pre-defined range for pH and water level can be configured by growers depending on the needs of their hydroponic or aquaponic system.

F_5 **Operate for at least 8 hours in the event of a power supply failure or outage.** The system must also send an alert to growers indicating that there was a power failure. Alerts should occur a 1 minute of the power failure.

F_6 **Give growers the ability re-calibrate sensors and actuators.** These re-calibrations can be made at any time.

4.2 Non-Functional Requirements

The following is a list of non-functional requirements for this project. This project must:

NF_1 **Cost less than $300 CAD per system.** Additional monthly servicing fees of must also be less than $5 per month.

NF_2 **Be designed to work with any small-scale aquaponics or hydroponics systems**. For this project, small-scale aquaponics or hydroponic systems have under 200 plants and under 3000 gallons of water.

NF_3 **Ensure that only permitted growers can monitor and control hydroponic or aquaponic systems.** Future administrators of our project must enable growers to monitor and control a given hydroponic or aquaponic system. Otherwise, access to monitor a given hydroponic or aquaponic system will not be permitted.

NF_4 **Be water resistant.** An IP rating of IP67 (Protected from immersion between 15 centimeters and 1 meter in depth) must be satisfied.

NF_5 **Be able to monitor different or additional aquaponics or hydroponics system variables, depending on the grower's preference.**

NF_6 **Measure all critical system variables within an accuracy of 5%.**

NF_7 **Maintain all controlled variables within an accuracy of 10%.**

5 Constraints

The following is a list of constraints on our design:

C_1 **All software developed must be open-source, with appropriate licensing to allow for legal modification, duplication, and sharing.** The license we have chosen is the GNU General Public License v3.0 as it allows the community to make changes and to use the code for personal purposes but prevents distributing closed source versions.

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