NEMO: AN ARDUINO AQUARIUM MONITORING SYSTEM CONTROLLED BY AN ANDROID MOBILE APPLICATION

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ABSTRACT

KATRINA ANNE NUGUID SALVADOR, University of the Philippines Los Baños, JUNE 2020. **NEMO: AN ARDUINO AQUARIUM MONITORING SYSTEM CONTROLLED BY AN ANDROID MOBILE APPLICATION**
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The growing popularity of mobile applications comes from its ability to assist in a wide range of tasks and its portability. This study aims to create an aquarium monitoring system that is manageable, cost-efficient, and relevant. This study utilizes the customizability of Arduino microcontrollers, along with compatible sensors, to measure water temperature, water pH, and water turbidity. A mobile application is created to alert the user when the condition of the aquarium is not ideal, display the data from the sensors that are retrieved from a Firebase realtime database where the data is uploaded by the Arduino, and allow the user to control the aquarium's lighting supply.

INTRODUCTION

Background of the Study

The evolution of the basic mobile phone into smartphones that offer extensive capabilities and features made way to the first mobile applications. More specifically, the release of Apple's first iPhone in 2007 worked up the acceleration of mobile applications that they boast as a new service type that meet the needs of users - "Whatever you want to do, there is an app for it". (Wang, Liao, & Yang, 2013) From being used only for calling and texting, mobile phones have progressed into tools that support a wide variety of tasks such as music and movie streaming, online multiplayer gaming, navigating, travelling, reading news, etc. (Böhmer, Hecht, Schöning, Krüger, & Bauer, 2011) These mobile applications have different kinds of users, some are large industries that take advantage of these capabilities and incorporate mobile apps into their businesses, and some people use these mobile applications personally for their own hobbies such as stargazing, gardening, and maintaining an aquarium.

Understanding what happens inside your aquarium is important in ensuring that aquatic life remains healthy. In maintaining an aquarium, monitoring is usually done manually. A human may commit errors due to nature. Gathering data about the aquarium's current state must be done regularly and the user must be immediately alerted when problems arise (Rajesh, 2017). Drastic changes in the levels of water parameter values affect the life of aquatic animals. With the help of sensors and wireless technology, a system that is simple but is effective in terms of minimizing overall human work and error, would provide great assistance.

Statement of the Problem

Most elements dissolve in water and it becomes hard to determine the amount of material mixed in it. Checking the quality of water requires accuracy and hard work. It has become necessary to involve technology to produce a quick result from an efficient method to determine the quality of water (Sigdel, 2017).

Fish are usually delicate to changes in its surroundings and pollution or conditions that are not suitable for fishkeeping may lead to a high mortality rate.

Currently, there are already several existing aquarium monitoring systems available on the market and over the internet such as, multifunctional aquariums which have built-in controllers that are able to adjust water level, temperature level, oxygen level, etc., or other mobile applications, but these can be very complex and expensive (Ma & Ding, 2014).

Objectives of the Study

This study aims to create an Android application and an Arduino-based system that will be able to digitally monitor a freshwater aquarium using sensors and actuators. More specifically, the proposed application aims to perform the following:

1. To obtain data regarding the aquarium's current condition using sensors;

2. To be able to switch the aquarium LED using the application over WiFi;

3. To be able to display the aquarium's current conditions on a mobile application; and

4. To be able to notify the user regarding unacceptable changes in the aquarium's condition.

Scopes and Limitations of the Study

This study will be limited to small-scale home freshwater aquariums containing common tropical fish. The parameters that will be measured are:

1. Water temperature

2. Water pH

3. Water turbidity

The aquarium component that will use an actuator is:

1. LED

The mobile application was developed by the researcher herself and will not be uploaded to the Google Play Store.

The accuracy of the data is dependent on the specifications of each sensor.

Arduino clones will be used for prototyping.

Due to the ongoing quarantines caused by the COVID-19 pandemic, an actual aquarium is not available for testing which involves physical contact. Instead, a 500ml sample of water from the aquarium is obtained for testing.

Significance of the Study

With the evolution of technology, more and more tasks become easier to complete because almost everything can be done with the help of mobile applications.

With the use of a mobile application and an internet connection, a user will be able to know the current state of his/her aquarium without personally assessing and measuring the water's condition. When this system is implemented on a large scale, it may be used in monitoring the water quality of fish farms.

REVIEW OF LITERATURE

Ideal Aquarium Condition Parameters

For a freshwater aquarium, the ideal measurement of water temperature falls within the range of 22.22-27.77°C and the ideal level of water pH falls within the range of 6.5-7.5 (*Proper Water Parameters for Home Aquariums*, n.d.). Most, but not all, species of tropical or freshwater fish can thrive on the mentioned pH levels. This is the reason behind why some fish are usually kept separate in different tanks with different pH levels. The safe turbidity level for long-term exposure is up to 3 NTU and fish begin to show signs of stress at 10 NTU. (*Suspended Solids and Turbidity Requirements of Freshwater Aquatic Life*, 2006)

It is vital to monitor the temperature of your aquarium's water. For tropical fish, heat is necessary during the colder months of the year. Many aquarists living in places with temperate climates face the opposite problem during summer, which is, keeping the aquarium from overheating (*Aquarium Temperature Control: Tropical Fish Hobbyist Magazine*, n.d.).

As the water's pH increases, so does the ammonia percentage. Ammonia is toxic and at high pH levels, it limits an organism's ability to purge itself of waste. Keeping your aquarium pH stable not only reduces stress on the fish, helps them resist disease and tolerate stressors but can also dramatically improve growth, behavior, and overall appearance (Costa, Kevin, Hanna, University, & of Florida, n.d.).

Another measure of water quality is turbidity. It is the cloudiness or haziness of a fluid caused by a multiplicity of individual particles that are generally invisible to the naked eye, similar to smoke in air. It is basically an optical determination of water clarity. Turbidites may appear in the form of milky-gray water or as a greenish stain in the water. Milky or green stains indicate an algal or bacterial bloom. This phenomenon can happen quite suddenly and be caused by fluctuations in seasons (*Water turbidities in the aquarium - Aquascaping Wiki*, n.d.).

The species that inhabit aquariums will be impacted in varying degrees by a constant level of light. To mimic the light available in a species' habitat, aquarium owners can use day and night lighting to approximate the light levels in a natural environment. These night lights, or Moon Lights, as they are called, give the fish keeper the opportunity to observe nocturnal behavior (Reich, 2019). Bright light also helps enrich the color of the fish. Bright light helps darken the pigments of many fish, making them stand out.

Lighting is a major part of having a visually pleasing community aquarium. The right lighting is very beneficial to aquatic plant life and therefore, to the fish and aquatic creatures in the aquarium as well.

Internet of Things and Wireless Sensor Networks

The Internet of Things or what is more commonly known as IoT involves a network of physical devices embedded with electronics, sensors, and actuators which can collect, connect and exchange data with each other. Lately there has been considerable growth in the development of actuators and sensors (Razzaque, Milojevic-Jevric, Palade, & Clarke, 2016). A wide range of industries are giving IoT growing attention as technological and societal pressures call for their innovation. One of the essential IoT technologies which is the Wireless Sensor Network (WSN), is mostly used for maintenance and tracking systems. By analyzing data in real time, users such as companies save time and money involving preventive maintenance (Lee & Lee, 2015)

Arduino

An Arduino is an open-source platform used for constructing and programming electronics. It can receive and send information and commands to most devices through the internet, a local network, a bluetooth connection, or simply through physical electrical connections. Today, Arduino microcontrollers are being used a lot in microcontroller programming because of its usability and affordability. An Arduino can help you read information from input devices such as sensors, antennas, and can also send information to output devices such as LED, Speakers, LCD Screen, or even a user-made mobile application (Badamasi, 2014). Moreover, Arduino microcontrollers are known for their customizability wherein you can tailor almost all of the variables in a way that would perfectly cater your project.

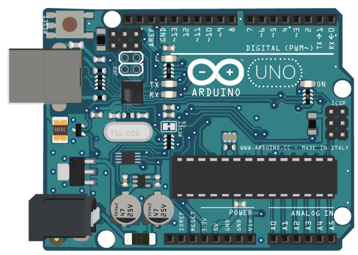


Figure 1. An Arduino UNO R3 Microcontroller

Similar Studies

A study in 2017 by Shrenika tried to solve the problem of a water tank's stainless steel water level sensors that get corroded by some chemicals. The researchers used Arduino, an Arduino-compatible ultrasonic sensor, and LabVIEW - a visual programming platform. The system had a big advantage compared to existing sensors in terms of data visualization and avoiding corrosion by using a non-contact sensor. It utilizes actuators as well for it can also switch on the pump when the water level is low and turn it off when the tank is already full.

Another study by Singh and Saikia in 2016 is about an Arduino-Based Smart Irrigation System that monitors the temperature and moisture of the soil. The user can monitor the moisture and turn on water pumps through a button that is connected to the system. The amount of water from the water pump can also be measured through the use of a water flow sensor.

Just like this study, both studies mentioned earlier make use of Arduino microcontrollers, ESP8266 WiFi Module, sensors, and actuators. For experimental purposes, all studies are done in a small scale but can easily be expanded to be able to supply for larger projects or systems.

METHODOLOGY

Development Tools

Hardware

1. 64-bit Laptop Computer running on 8GB RAM and Intel® Core^{TM} i7 3670QM
2. Samsung Galaxy S10
3. Arduino UNO R3 CH340G SMD microcontroller
4. ESP8266 ESP-01 Arduino WiFi Module
5. DS18B20 Water Temperature Sensor; Range: -55°C to +125°C; Accuracy: $\pm 0.5°C$
6. SEN0161 Gravity: Analog pH Sensor; Range: 0-14pH; Accuracy: $\pm 0.1pH$
7. SEN0189 Gravity: Arduino Turbidity Sensor
8. Arduino NeoPixel Stick - 8 x 5050 RGB LED
9. Breadboard
10. Jumper wires
11. 1% tolerance 1/4 watt resistors (2.2k, 4.3k, 4.7k, 10k ohms)

Software

1. Windows 10 Operating System
2. Android Studio version 3.1.3
3. Arduino IDE 1.8.6

4. Android 10

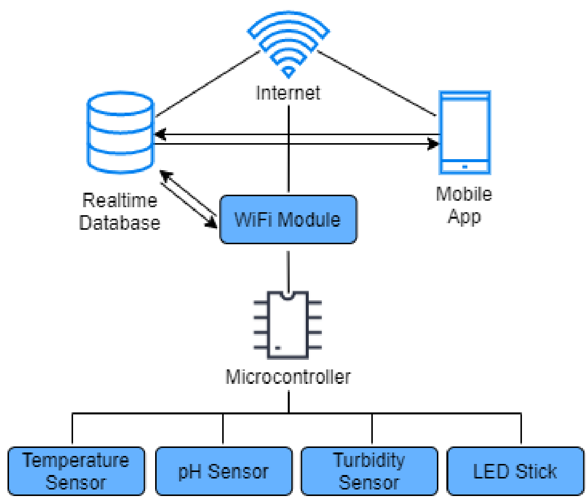
5. Google Firebase Realtime Database

Methods

Hardware Assembly

The flow of the whole system follows the diagram in figure 2 wherein the sensors, the actuator, and the WiFi module are all physically connected to the microcontroller while it communicates with the app through the database and an internet connection.

Figure 2. Diagram of the system's network

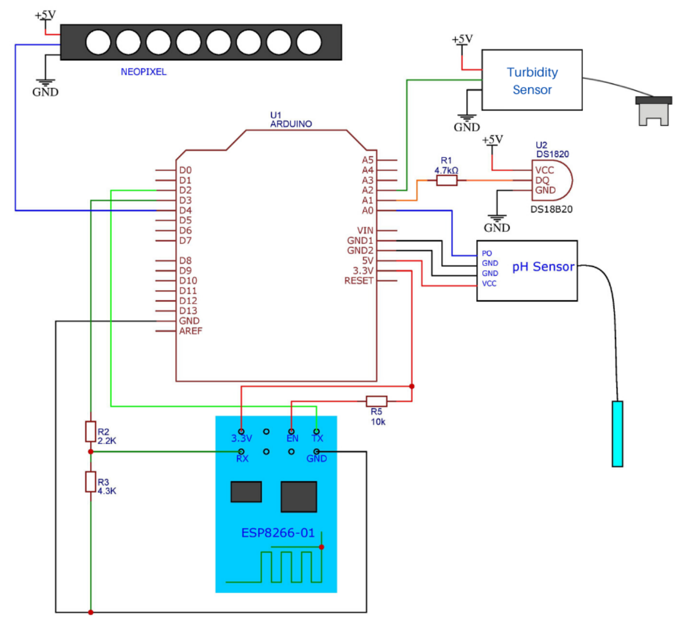


For prototyping, the sensors and the actuator are connected to the controller using a breadboard that follows the schematic shown in figure 3 and implemented as shown in figure 4.

Database Setup

Google Firebase offers a realtime database that can communicate with the ESP8266 WiFi module and Android Studio, where the mobile app will be created. This database

Figure 3. Nemo electronic circuit schematic

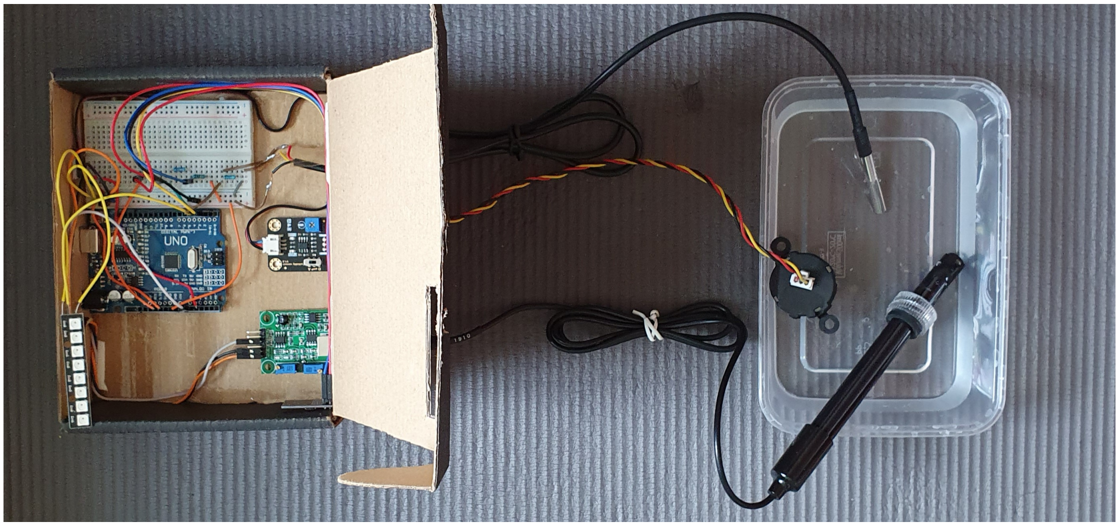


uses the JSON format. The database can handle multiple users for a single app but for the purpose of this study, the database can handle only one generic user. The database is set up by signing-in using a Gmail account and selecting the ”Realtime Database” option wherein some project details, such as the title and privacy settings, are needed. The privacy is set to public in order for the Arduino and the mobile app to be able to modify the contents of the database.

ESP8266 WiFi Module Initialization

Since the ESP8266 WiFi Module is also a microcontroller, it is capable of storing and running a code separately from the Arduino Uno. It doesn’t have a USB port so the Arduino Uno was used as an adapter to upload programs to the WiFi Module. The code for the WiFi Module includes the credentials (SSID and password) of the network to be used

Figure 4. Nemo prototype



by the Arduino Uno, the database's unique url, and the database's provided authentication key. The code for the WiFi module also contains the algorithm of the formatting of data from the Arduino Uno to be sent to the database and vice-versa.

Data Gathering

The temperature sensor reads and returns the temperature as it is but the pH sensor and turbidity sensor return voltage values that need to be converted to either NTU or pH value. The readings from the sensors fluctuate due to the noise from the voltage line and the signal line so they need to be averaged first before being converted to the corresponding unit. The pH sensor and turbidity sensor need to be calibrated first using buffer solutions. Calibration is done only once. Buffer solutions have fixed values that are used to map voltage to the values in order to come up with a formula for the conversion. The pH sensor returned a reading of 551.0 for 7.00 pH and 657 for 4.02 pH. Since the two pairs of values can function as coordinates ((551, 7) and (657, 4.02)), when each point is plotted and connected, they form a straight line. The equation of that line will be able to tell the corresponding pH value for any sensor reading that falls on the length of the line. The equation of any straight

Figure 5. Contents of the database

line is $y = mx + b$ wherein x is the sensor reading and y is the corresponding pH value. m and b are derived using the values from the buffer solution.

$$m = (4.02 - 7)/(657 - 551) = -0.0281$$

$$b = |(-0.0281 * 551) - 7| = 22.4831$$

The main conversion formula for the pH sensor is:

$$y = (-0.0281 * sensorReading) + 22.4831$$

The turbidity sensor returned a reading of 900 for 1 NTU and 693 for 15 NTU. Following the same steps from the pH sensor, m and b are derived using these values.

$$m = (1 - 15)/(900 - 693) = -0.0676$$

$$b = |(-0.0676 * 693) - 15| = 61.8468$$

The main conversion formula for the turbidity sensor is:

$$y = (-0.0676 * sensorReading) + 61.8468$$

The code containing these conversions also include the command that is able to switch the LED on or off and the function that can get the status of the LED.

Data Analysis

Data that are collected from the sensors at the controller are compared with the threshold parameter values. Table 1 shows the range of the values that are considered as safe and ideal for the fish.

Table 1. Threshold values

pH	**Temperature**	**Turbidity**
pH	Celsius	NTU
6.5 - 7.5	22.22 - 27.77	0 - 10

Data Transformation on the Mobile Application

The mobile app was created using Android Studio. The app has 2 activities, the dashboard and the history. Firebase's library is used in order to communicate easily with the data from the database. The dashboard displays the values from each sensor, which are retrieved from the database, along with a gauge for easier visual interpretation. There is also a card that displays the status of the LED and a button that serves as a light switch. On this activity, the user can save the currently displayed values and it will be saved on the history page where there are 3 line graphs, one for each component of the water quality. With the line graph, the user can easily compare trends among the saved data. The current date and time are saved and displayed along with the data. The user can also clear the contents of the history. When the values in the dashboard reaches a certain threshold set earlier, it notifies the user about which component needs attention.

Figure 6. Dashboard

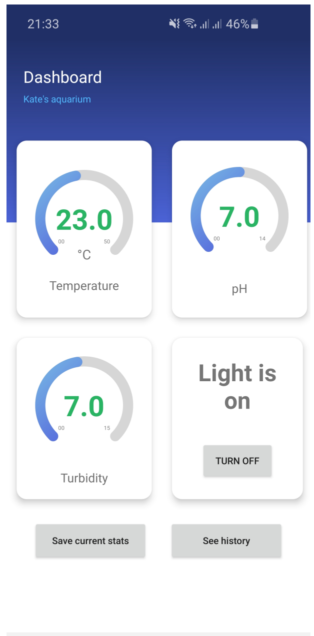
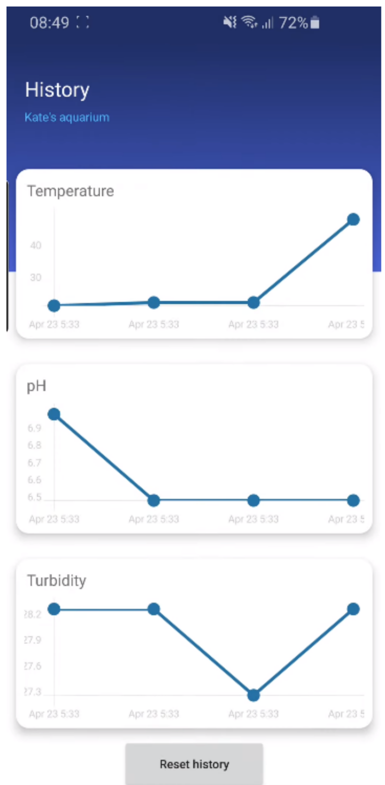


Figure 7. History



RESULTS AND DISCUSSION

When turning on or restarting the Arduino, the mobile application needs to be closed and opened only after the Arduino has connected to the internet. This is done in order for the data to load properly on the mobile application given that it is connected to the internet. The Arduino and the mobile application don't need to be connected to the same network to function, both just need to be connected to a network simultaneously.

Testing the system on water from an aquarium and on clean water yielded the appropriate corresponding values for temperature and pH but varied on the turbidity level. Since the turbidity sensor uses light transmittance as a way to determine the cloudiness, the most accurate readings of turbidity are produced from a well-lit aquarium.

The mobile application has also successfully notified the user about which component needs attention. That particular component's value on the dashboard is also displayed in red or yellow instead of green to indicate that it is not ideal for the fish.

SUMMARY AND CONCLUSION

The use of the mobile application has helped in minimizing the time of monitoring the aquarium, specifically its water quality, compared to using separate complex materials that individually measure each component, manually recording the data and manually referring to the ideal values.

When implemented on a larger scale, this system can be used on fish farms, rivers, aquaculture, rehabilitation sanctuaries for endangered aquatic animals that need constant monitoring and have strict environment requirements, etc. For a large-scale implementation, this system is comparatively a cost-efficient investment. The Arduino-based system upheld its ease of implementation, operation, maintenance and cost.

The availability of an internet connection is limited in certain places. The implementation or addition of an SMS notification system may be done by using an Arduino GSM shield in order to allow the Arduino send and receive messages.

The vast use of mobile applications is a big advantage to interdisciplinary fields. Technology is continuously evolving and is reaching more disciplines which means there are still a lot of helpful and useful breakthroughs to be discovered as we continue to study the different possibilities in using mobile applications.

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