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A Low-Cost Electronic Food Nose IoT-Based Fish Quality Monitoring System

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Fish is one of the primary sources of food that human beings can consume. With that idea, this study aims to monitor fish quality by monitoring specific parameters to keep track of fish's safety levels, which are unnoticeable to the naked eye. This study focuses on helping cafeteria owners be more observant of the quality of fish they are serving their customers. A mobile application is developed through the MIT App inventor to have a user-friendly system that can aid users in quickly identifying the data transmitted from the device using the internet. With the help of the Rapid Application Development (RAD) process model, the researchers were able to implement the concept of the fish quality monitoring system. The Arduino Wemos D1 R1 development board acts as the main component of the device. The built-in ESP8266 Wi-Fi module in the microcontroller allows data transmission from the device to the ThingSpeak application, which acts as the system's online database. The process of how the system works is that the MLX90614, MQ4, and MQ137 sensors gather the Temperature, Methane, and Ammonia gas measurements. Once the device has processed all the data, the outputs can be displayed on the mobile application so that the user can decide if they still want to check the output graph.

1. Introduction

Food consumption is vital to the survival of every human being (Prajwal et al., 2020). Therefore, cafeteria owners buying sacks of fish may need to be aware of the daily stale fish they buy at the market. According to Malahayati (2021), food wastage has significantly impacted the environment and the economy. However, there must be a balance between reducing food waste and maintaining food quality. To help prevent consuming stale and possibly spoiled fish, an electronic food nose was developed to monitor the Temperature (°C), Methane (CH_4), and Ammonia (NH_3) levels that the fish emit, as Raj et al. (2020) mentioned, it is as a smell detector sensor. Electronic noses are instruments comprising an array of semi-selective gas sensors and pattern-recognition methods (Falasconi et al., 2012). Electronic food noses (Slupek et al., 2020) are currently an emerging technology when looking at food quality control, whether for detecting bacteria, microbes, or overall food safety, and are becoming an essential technology for everyone. The bacterial growth of a fish means the beginning of fish spoilage, which releases Methane (Garg et al., 2021). It also emits Ammonia (Yavuzer, 2021), which contributes to increasing histamine levels. With Temperature and MQ-series gas sensors, the quality monitoring can identify whether the fish can still be cooked and stored depending on the user or if it should be for disposal. Monitoring these parameters that a fish contains can aid in preventing the consumption of spoiled fish, and the Temperature must be maintained (Christiena et al., 2020) to preserve freshness. A similar study by Arun Kumar G. (2020) also implemented an Arduino sensor-based approach for detecting food spoilage.

The main objective of this study is to create an electronic food nose that monitors the quality of the fish that can help cafeteria owners prevent the spoilage of the fish and help them determine which fish to cook or store first. The benefit of the system is to help cafeteria owners from serving spoiled fish. The design may also encourage households to use the device to check whether the fish is spoiled or not after buying the fish from the market. Also, it may aid sanitary inspectors in determining whether the cafeteria's fish is fresh, and they can monitor whether the cafeteria's prevention and control of the disease is one of their priorities. The market can also

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benefit from this study if customers want to know whether the fish is fresh. Future users can help prevent spoiled fish consumption and lessen food waste. Figure 1 shows that the study framework consists of input, process, and output. The input of the system is the Temperature (°C), Methane (CH_4), and Ammonia (NH_3) level sensor readings. The process involves data processing and transmission, while the output includes the Mobile GUI, the Fish Quality Status and Index, and the Decision notification.

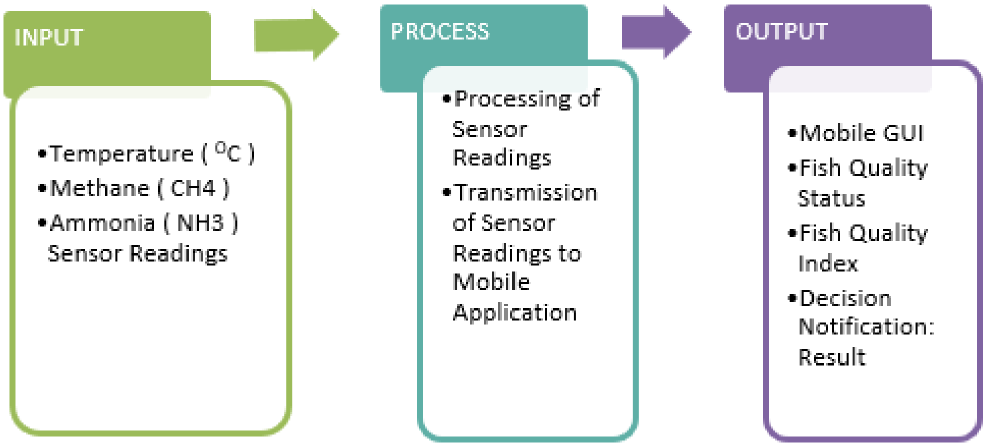

Figure 1: Conceptual Framework

2. Methodology

This study utilized the Rapid Application Development (RAD) process model throughout its development. Rapid Application Development (Beynon-Davies et al.,1999) gives the benefit of having an immediate project turnaround designed for working in a fast-paced environment such as software development since it focuses on maximizing the prototype development while minimizing the planning stage.

The process of monitoring the quality of fish followed the quantitative research design. The procedure started with the sensors measuring the fish's Temperature, Methane, and Ammonia connected to a WEMOS D1 R1 development board. The WEMOS microcontroller integrated with the ESP8266 Wi-Fi module can transmit the processed input data to the ThingSpeak application. The ThingSpeak application software can communicate using Wi-Fi modules and store various data displayed according to the user's desires and incorporated into the mobile application for the user to view the obtained output. Tests were conducted for fresh and rotten fish at 24-hour intervals to show the difference in data received by the prototype. In addition, the conducted monitoring part of the study at a 4-hour interval for each test increased the data received by the device. Eq(1) shows the Paired T-test formula to statistically determine the significant difference among the parameter changes in testing fresh versus rotten fish.

$$t = \frac{\overline{x_d} - u_0}{s_d \,/\, \sqrt{n}} \tag{1}$$

Figure 2 shows the overall design concept of the IoT-Based Fish Quality Monitoring System. As seen in Figure 3, the user turns on the device by connecting the USB power cable to the power source. The sensors would then require a preheat of around 1 min before the complete use of the device; once done with the preheat, the user can then proceed and open the lid of the device and place the fish inside. After placing the fish inside and the lid of the container is closed, the sensors, which are the MQ4, MQ137, and MLX90614, will all read the corresponding data values intended for each sensor. The values read by the device will then be sent to the ThingSpeak Database using the Wi-Fi module of the Wemos D1 R1. ThingSpeak will send its data to the mobile application, which will then process the data obtained using the Fuzzy Logic if-then algorithm to determine the connection between each variable. The pseudocode of the Fuzzy Logic if-then was based on the fact sheet, as shown in Figure 4. Once done, the user can remove the fish from the container and turn off the device.

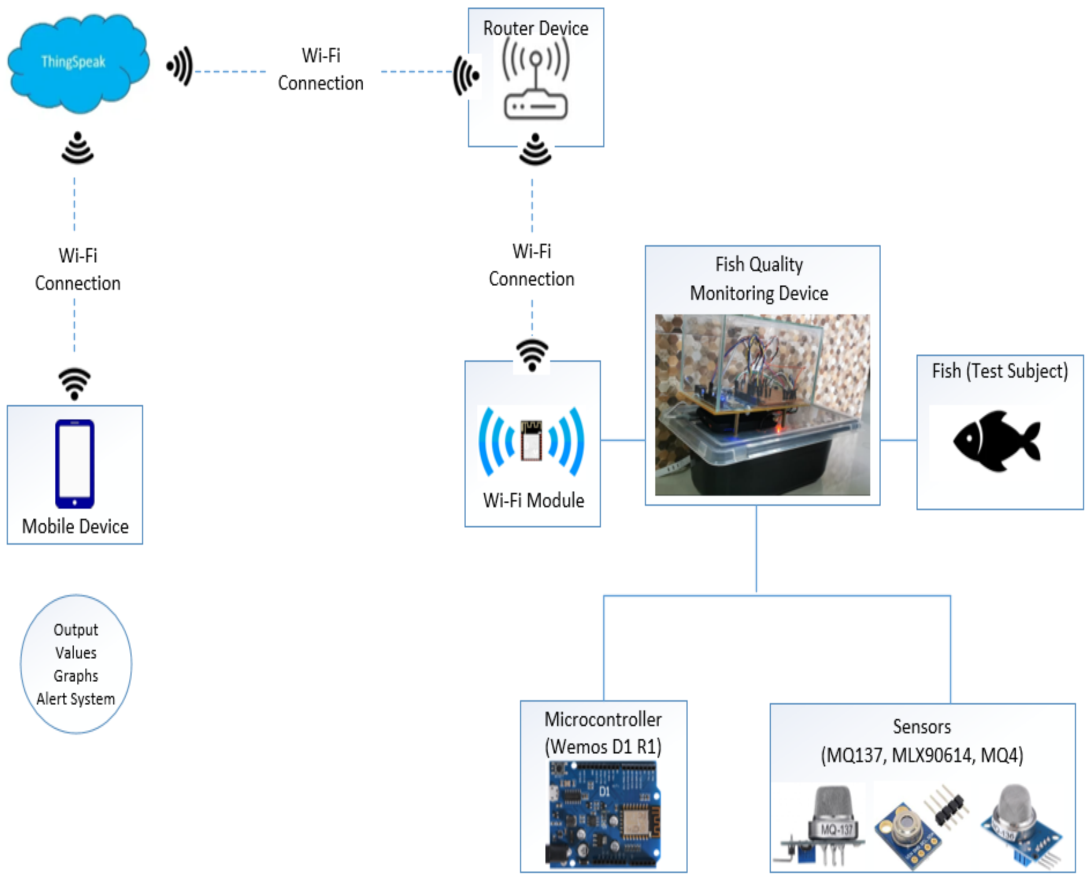

Figure 2: Design Concept of IoT-Based Fish Quality Monitoring System

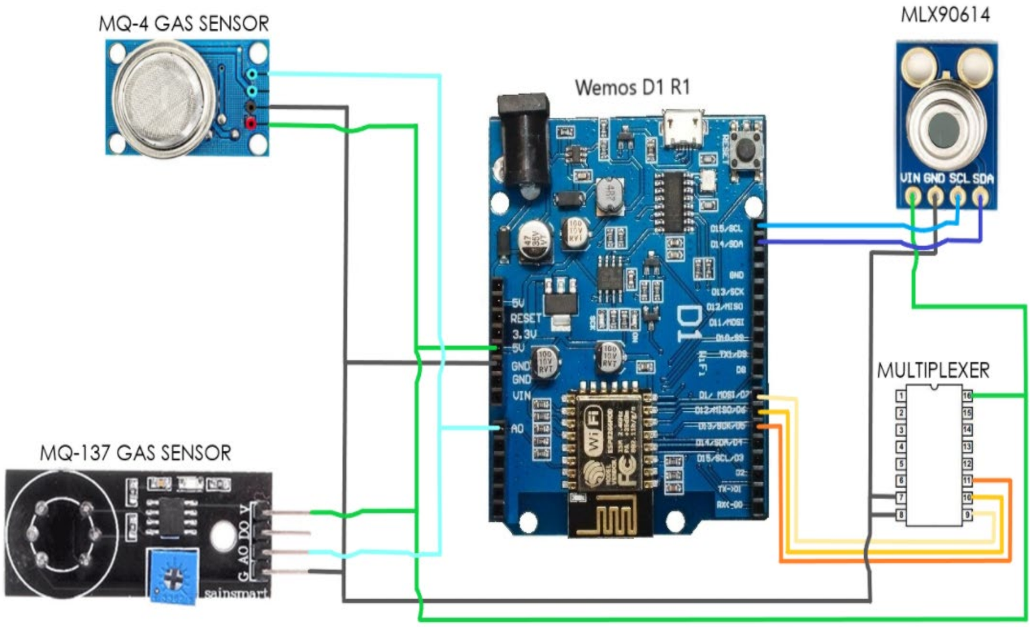

Figure 3: Block /Circuit Diagram of IoT-Based Fish Quality Monitoring System

```
when clock Timer
do call readArduino
    set gettemp Text to get global temp
    set getmethane Text to get global methane
    set getammonia Text to get global ammonia
        if
            get global temp <60
    then set description_temp Text to "FISH IS COOKED PROPERLY"
    else if
        get global temp >4 and get global temp < 59
    then set description_temp Text to "FISH IS AT ROOM TEMPERATURE"
    else if
        get global temp >-35 and get global temp < 3
    then set description_temp Text to "FISH IS STILL FROZEN, DEFROST
FIRST"

        if
            get global methane >1000
    then set description_methane Text to "HIGH LEVELS OF METHANE"
    else if
        get global methane >500 and get global methane < 999
    then set description_methane Text to "MODERATE LEVELS OF
METHANE"
    else if
        get global methane >0 and get global ammonia < 499
    then set description_methane Text to "LOW LEVELS OF METHANE"

    If
            get global ammonia >300
    then set description_ammonia Text to "HIGH LEVELS OF AMMONIA"
    else if
        get global ammonia >150 and get global ammonia < 299
    then set description_ammonia Text to "MODERATE LEVELS OF
AMMONIA"
    else if
        get global ammonia >0 and get global ammonia < 149
    then set description_ammonia Text to "LOW LEVELS OF AMMONIA"

If
            get global temp >4 and get global temp <59 and get global methane
>0 and get global methane <999 and
            get global ammonia >0 and get global ammonia < 299
    then set description_result Text to "FISH CAN STILL BE COOKED OR
STORED"
    else if
        get global temp >4 and get global temp <59 or get global methane
>1001 or get global ammonia>301
    then set description_result Text to "FISH IS ALREADY SPOILED ,
DISPOSE IMMEDIATELY"
```

Figure 4: Pseudocode of FUZZY IF-THEN Algorithm

3. Result

As shown in Figures 5 and 6, the graph of the parameter values consisting of data gathered from the sensor readings of the Electronic Food Nose IoT-Base Fish Quality Monitoring System for fresh and rotten Oreochromis Niloticus (Philippine Tilapia), respectively.

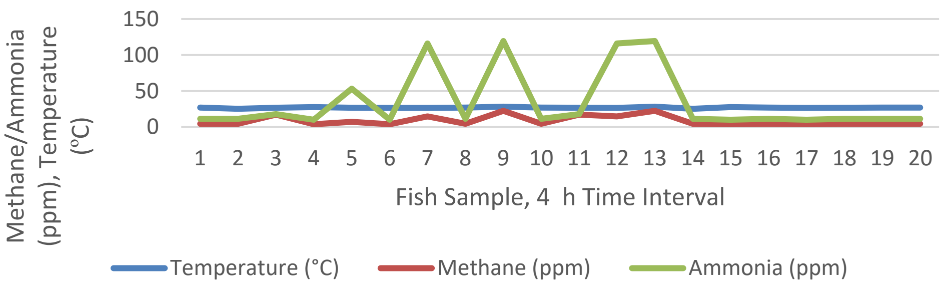

Figure 5: Graph for Sensor Data Readings of IoT-Based Fish Quality Monitoring System (Fresh Fish)

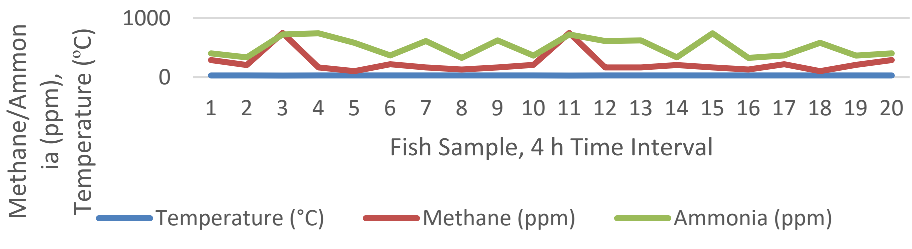

Figure 6: Graph for Sensor Data Readings of IoT-Based Fish Quality Monitoring System (Rotten Fish)

Figures 7a, 7b, and 7c show the graph comparison between parameters for Temperature, Methane, and Ammonia based on the data gathered from the sensor readings of the Electronic Food Nose IoT-Base Fish Quality Monitoring System for "Fresh" and "Rotten" Oreochromis Niloticus (Philippine Tilapia). In Figure 7a, the results of the paired-t test indicated that there is a significantly large difference between Fresh Fish Temperature (°C) (M = 26.9, SD = 0.7) and Rotten Fish Temperature (°C) (M = 30, SD = 0.5), t (19) = 14.5, $p < 0.001$. In Figure 7b, the results of the paired-t test indicated that there is a *significantly* large difference *between Methane measurements of* Fresh Fish (M = *8.6, SD* = 6.7) and *Rotten* Fish (M = *241, SD* = 181), t (19) = 5.8, $p < 0.001$. In Figure 7c, the results of the paired-t test indicated that there is a significantly large difference between

Ammonia measurements of Fresh Fish (M = 35.2, SD = 43.4) and Rotten *Fish* (M = *509.6, SD* = 160.4), *t* (19) = 14.3, p < 0.001.

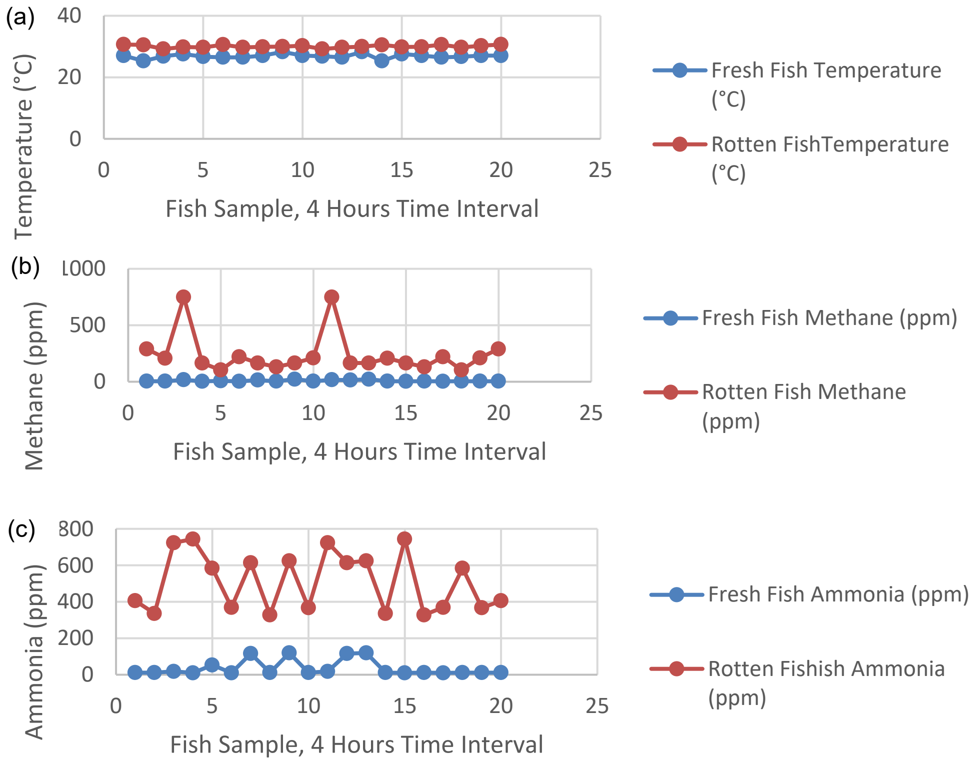

Figure 7: (a)Temperature, (b)methane and (c)Ammonia measurement comparison between fresh fish and rotten fish

In launching the mobile application, the home screen will be the first the user will see, as shown in Figure 8a.

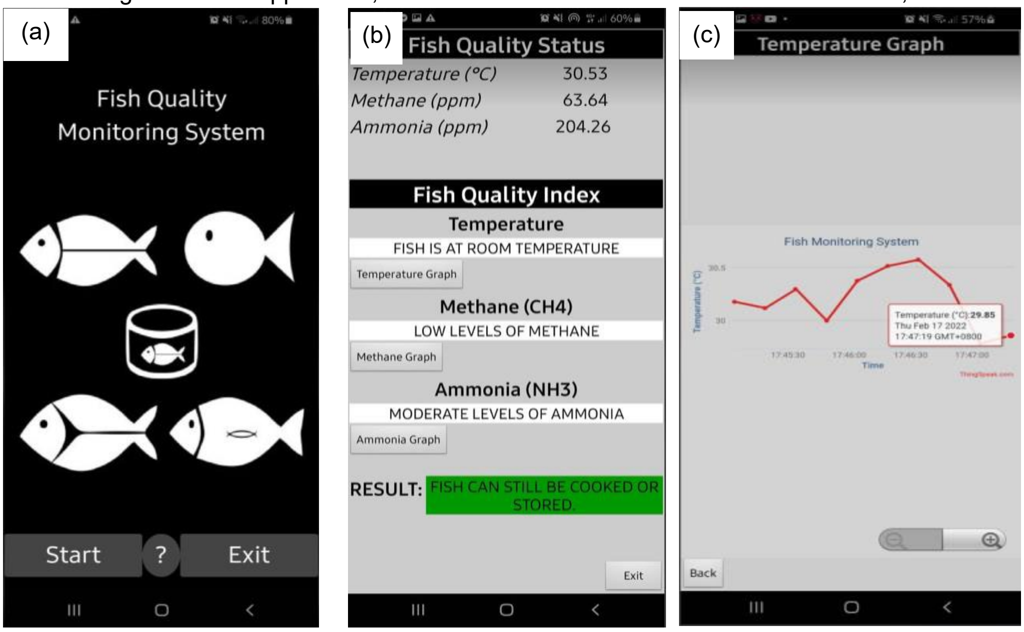

Figure 8: Mobile Application (a) Home Screen, (b) Fish Quality Status and Index Screen, (c) Graph Viewer

The user will have three options: start the application, know the mobile application's functionality with the button with a question mark logo, or exit the mobile application. As shown in Figure 8b, the application can display both the values of the monitored parameters and the status of the fish, in which the mobile application can decide whether the fish can still be cooked or stored or for disposal, depending on the result shown on the mobile application. Another feature of the mobile application is that it can show the graphs with the buttons assigned for each corresponding parameter shown in Figure 8c.

4. Conclusions

The Electronic Nose IoT-Based Fish Quality Monitoring System successfully monitored and evaluated data based on the test conducted. The built food monitoring system can accommodate fish that can fit inside the container. The sensors inside the container can detect the Temperature, Methane, and Ammonia and return reliable data to the database. If internet connectivity is available, the algorithm developed inside the Arduino IDE can successfully retrieve and send data from the Wemos to Thingspeak using its integrated ESP8266 module. The mobile application developed can retrieve the data from the Thingspeak database and perform the evaluation. Changes in the color of the result indicate whether the received values will show safe or not with the analysis taken from collected evaluated fish data. Based on the study, Methane and Ammonia were released at a much higher concentration when the spoilage process started The Paired T-test results show a significant difference in the Temperature, Methane, and Ammonia measurements between Fresh and Rotten Fish, proving that the device successfully differentiated rotten fish from fresh fish using these parameters.

As for the recommendations, to further monitor the parameters more accurately, use more or better sensors to measure different variables to improve the device. Sensors with machine learning capability can also identify whether the fish is rotten or fresh. The device can be made with a robust compartment to prevent the odor from sticking to the container. Furthermore, the program structure can be improved along with more details to get more accurate results. The testing of each fish was only done in 3 min for the sensor to send more accurate results, but it is better to allow it to run for a longer time to stabilize the results.

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