Astana IT University

Assignment 2 - IoT Sensor Data Collection & Visualization
PROJECT REPORT
IoT-Based Water Quality Monitoring System for Aquaculture Ponds

Course: Industry 4.0
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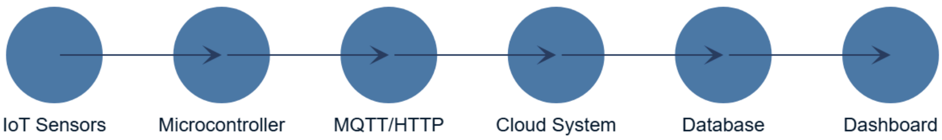
1. Introduction & Objectives

Aquaculture ponds require stable and well-controlled water quality to ensure the health, growth, and survival of fish. Parameters such as pH, dissolved oxygen, temperature, and turbidity directly affect fish health and survival. In many fish farms, water quality is still monitored manually and only a few times per day. This approach is slow and may fail to detect problems in time, fish may already be stressed or dying.

The goal of this project is to use Internet of Things (IoT) technology to continuously monitor water quality in aquaculture ponds and detect unsafe conditions early, before they harm fish or reduce productivity.



2. IoT Sensors and Data Collection

Step 1: Collecting the Data

For this project, I used a real IoT-based dataset called Ponds Water Quality Data, which contains water quality measurements collected from aquaculture fish ponds using Internet of Things (IoT) technology.

The data was originally collected using multiple water quality sensors connected to an Arduino microcontroller. These sensors were selected to measure key parameters that directly affect fish health:

1. **Nitrate** – a byproduct of ammonia breakdown
2. **pH** – measures how acidic or alkaline the water is
3. **Ammonia** – toxic waste produced by fish and organic matter
4. **Temperature** – affects fish metabolism and oxygen solubility
5. **Dissolved Oxygen (DO)** – shows how much oxygen is available for fish
6. **Turbidity** – indicates how clear or dirty the water is
7. **Manganese** – monitored for overall water quality balance

index	Station	Date	NITRATE(PPM)	PH	AMMONIA(mg/l)	TEMP	DO	TURBIDITY	MANGANESE(mg/l)
0	station1	01-02-2022 08:00	18.3	5.7	0	17.69	11.6	86.1	0.71
1	station1	01-02-2022 08:20	3.6	5.1	0	19.42	10.5	71.8	0.62
2	station1	01-02-2022 08:40	13.1	5.5	0	18.6	10.3	75.9	0.73
3	station1	01-02-2022 09:00	18.1	5.2	0.1	19.1	9.4	70.3	0.64
4	station1	01-02-2022 09:20	10.8	5.2	0.1	18.57	8.8	66.9	0.68

Each sensor continuously measured its parameter. For example, the pH sensor generated voltage signals proportional to pH levels, while the dissolved oxygen sensor used amperometric methods to measure oxygen concentration. This ensured accurate and continuous data collection. To enable real-time data transmission, a NODEMCU (ESP8266) module was used. This module provided internet connectivity and acted as a bridge between the Arduino board and the cloud storage system.

Step 2: Connecting the "Brain" (Python Analysis)

After obtaining the dataset, I used an Python environment to analyze the sensor data. In this project, Python acted as the "brain" of the system.

Using Python, I was able to:

1. Read and organize large volumes of sensor readings
2. Process time-series data efficiently
3. Identify patterns such as unstable pH values or dangerously low dissolved oxygen levels

I used Python libraries to create visualizations that clearly show how water quality parameters change over time. This step was important because it converted raw numerical data into meaningful information that can be easily understood by humans.

4. MQTT / HTTP Communication

In real IoT systems, sensors do not store data locally. Instead, sensor readings are transmitted to the cloud using lightweight communication protocols such as **MQTT** or **HTTP**.

Step-by-Step Communication Process

1. Sensors installed in fish ponds collect water quality data.
2. Sensors are connected to a microcontroller (Arduino / ESP32 / Raspberry Pi).
3. The microcontroller reads sensor values at regular intervals.
4. Data is formatted into a structured message (JSON).
5. Data is sent to the cloud using MQTT or HTTP.
6. Cloud systems receive the data for storage and visualization.

MQTT Communication

- The microcontroller acts as an MQTT client
- It connects to an MQTT broker
- Sensor data is published to a topic such as `ponds/water_quality`
- Cloud applications subscribe and receive data in real time

HTTP Communication

- The microcontroller sends an HTTP POST request
- Sensor data is included in the request body
- The server receives and processes the data

Example JSON message:

```json
{
 "station": "Pond1",
 "timestamp": "2024-06-01T10:00:00Z",
 "pH": 7.2,
 "temperature": 28.5,
 "dissolved_oxygen": 6.8
}
```

3. Data Storage

After transmission, sensor data is stored in the cloud for further analysis.

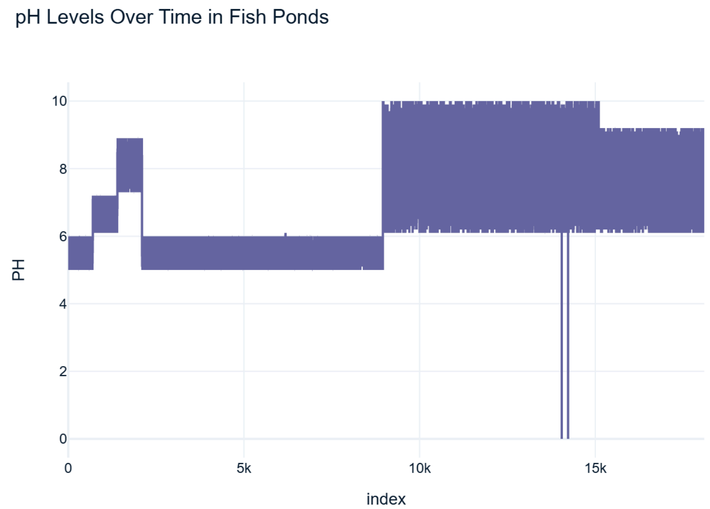
In this project:

- A **CSV file acts as a simple database**
- Each row represents one sensor reading
- Each column represents a water quality parameter or timestamp

4. Dashboard Visualization

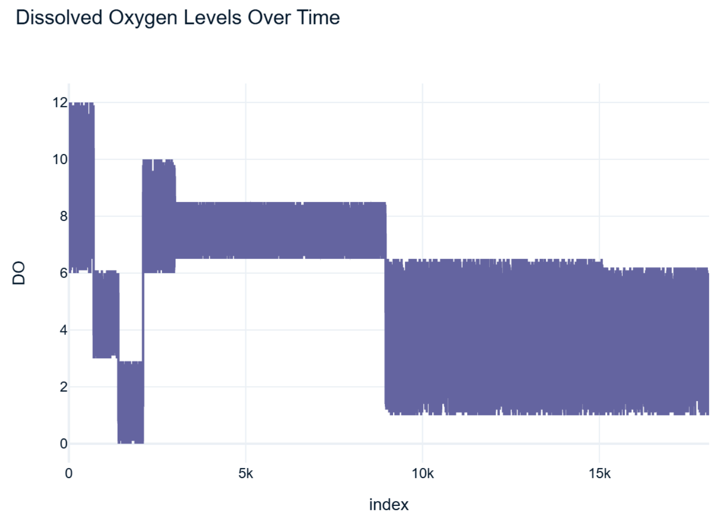
To make sensor data easy to understand, dashboards were created and viewed using **DataLab**. Stored data is analyzed and displayed using interactive visualizations instead of raw tables. The dashboard includes the following visualizations:

Figure 1: pH Levels Over Time



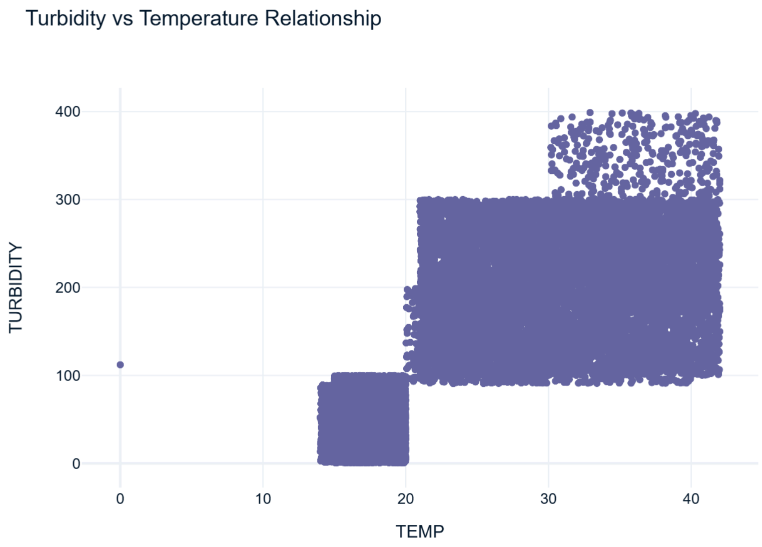
- Shows how pH changes throughout the monitoring period
- Helps identify sudden spikes or drops
- Supports stable pond management

Figure 2: Dissolved Oxygen Levels Over Time



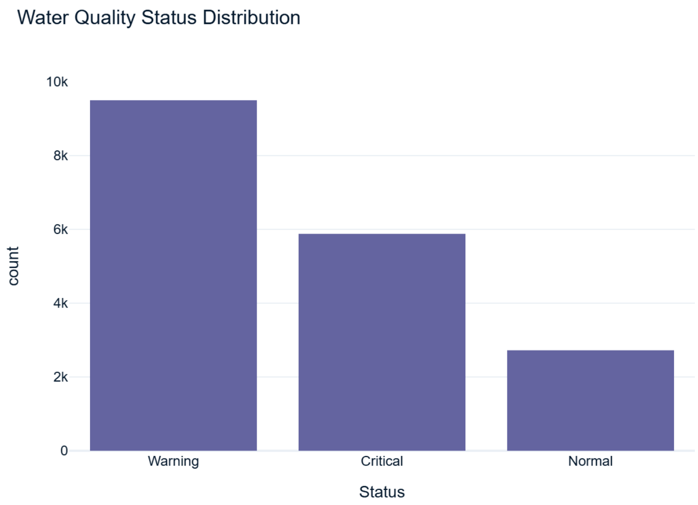
- Tracks oxygen availability for fish
- Identifies dangerous low-oxygen conditions early
- Helps prevent fish mortality

Figure 3: Turbidity vs Temperature



- Shows the relationship between water clarity and temperature
- High turbidity at high temperature increases fish stress
- Helps detect runoff or algal bloom events

Figure 4: Water Quality Status Distribution



- Categorizes readings into **Normal**, **Warning**, and **Critical**
- Provides a quick overview of pond health
- Supports fast decision-making

Using DataLab dashboards makes water quality monitoring clear, visual, and easy to interpret.

5. Results and Insights

Analysis of the dataset revealed several important insights:

- Water quality problems usually develop gradually
- pH instability and oxygen depletion often appear before critical events
- High turbidity combined with high temperature increases stress on fish
- Continuous monitoring enables early intervention

Key Insight:

Monitoring trends over time is much more effective than checking single measurements.

8. Conclusion and Future Work

This project demonstrates how IoT technology can significantly improve water quality monitoring in aquaculture ponds. By combining sensors, MQTT/HTTP communication, cloud data storage, and DataLab dashboards, fish farmers can detect unsafe conditions early and take preventive action.

Future Improvements

- Integrating AI models for predictive water quality analysis
- Developing a mobile application for real-time alerts
- Adding automatic control systems (aerators, filters)
- Integrating weather and environmental data

Conclusion:

IoT-based monitoring improves fish health, reduces economic losses, and supports sustainable aquaculture practices.

Dataset Source

Dataset used in this project: https://www.kaggle.com/datasets/apgopi/pondsdata