Fish Species Selection and Growth Monitoring for Sustainable Aquaculture

Project Team

Sajid Ali	21P-8023
Muhammad Nauman	21P-8045
Ammar Raza	21P-8004

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Supervised by

Mr./ Usman Wajid

Department of Computer Science

National University of Computer and Emerging Sciences
Peshawar, Pakistan

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Student's Declaration

We declare that this project titled "*Fish Species Selection and Growth Monitoring for Sustainable Aquaculture*", submitted as requirement for the award of degree of Bachelors in Computer Science, does not contain any material previously submitted for a degree in any university; and that to the best of our knowledge, it does not contain any materials previously published or written by another person except where due reference is made in the text.

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Sajid Ali	Signature: _______________
Muhammad Nauman	Signature: _______________
Ammar Raza	Signature: _______________

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The Department of Computer Science, National University of Computer and Emerging Sciences, accepts this thesis titled *Fish Species Selection and Growth Monitoring for Sustainable Aquaculture*, submitted by Sajid Ali (21P-8023), Muhammad Nauman (21P-8045), and Ammar Raza (21P-8004), in its current form, and it is satisfying the dissertation requirements for the award of Bachelors Degree in Computer Science.

Supervisor

Mr./ Usman Wajid Signature: ________________

____

Name of FYP Coordinator

FYP Coordinator
National University of Computer and Emerging Sciences, Peshawar

____

Dr. Head of Computer Science Department

HoD of Department of Computer Science
National University of Computer and Emerging Sciences

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Sajid Ali

Muhammad Nauman

Ammar Raza

Abstract

The project "Water Quality-Driven Fish Type Selection and Growth Monitoring for Sustainable Aquaculture" addresses key challenges in aquaculture, such as suboptimal fish growth, species mismanagement, and insufficient disease detection. Traditional fish farming methods often lead to inefficient resource use and lower productivity. This project proposes an advanced aquaculture system utilizing IoT and machine learning to monitor critical water quality parameters—pH, temperature, and turbidity—which directly impact fish species selection and growth. The system integrates modules for fish species classification, growth tracking, behavior monitoring, and disease detection, all linked with sensors for real-time data collection. A user-friendly interface provides alerts and actionable insights, empowering farmers to make timely and informed decisions. Initial findings indicate accurate fish species recommendations, improved growth rates, and effective disease prevention, contributing to sustainable and productive aquaculture practices. This solution enables optimized resource use, reduced environmental impact, and enhances the resilience of fish farming systems, supporting food security and the global aquaculture industry.

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Chapter 1

Introduction

The purpose of this investigation is to explore the potential of technology, specifically IoT and machine learning, in addressing the challenges faced by traditional aquaculture practices. The problem being investigated revolves around the inefficiencies and vulnerabilities in current fish farming methods, which hinder productivity and sustainability in the aquaculture industry.

The background of this problem is significant, as aquaculture has emerged as a vital source of sustainable protein in response to the rising global demand for seafood. However, traditional fish farming methods often encounter issues such as poor growth rates, unsuitable species selection, inefficient resource usage, and vulnerability to disease outbreaks. Previous work has highlighted these challenges, emphasizing the need for innovative solutions to enhance fish farming practices **?**.

This thesis posits that the implementation of a smart aquaculture system that leverages IoT and machine learning can effectively monitor essential water quality parameters, track fish behavior, detect diseases early, and ensure optimal fish growth. The general approach involves utilizing real-time data collection and analysis to improve decision-making in aquaculture management, ultimately aiming to increase productivity while minimizing environmental impact.

The criteria for this study's success include improved fish health and growth rates, reduced disease incidence, optimized resource usage, and increased overall productivity in aquaculture operations.

- The purpose of the investigation is to explore the role of technology in enhancing aquaculture practices.
- The problem being investigated is the inefficiency and vulnerability of traditional fish farming methods.
- The background of the problem highlights the rising demand for seafood and the challenges faced by traditional aquaculture, citing previous work that underscores the need for innovative solutions.
- The thesis asserts that smart aquaculture systems can leverage technology to improve fish farming outcomes.
- The criteria for the study's success include enhanced fish health, optimized resource usage, and increased productivity.

The smart aquaculture system aims to address the aforementioned challenges by continuously monitoring vital water quality parameters such as pH, temperature, and turbidity. These parameters are critical for ensuring optimal conditions for fish health and growth. By employing IoT sensors, the system collects real-time data, providing insights into the environmental conditions of the aquaculture system. This information allows farmers to take proactive measures to maintain water quality and ensure that fish thrive.

In addition to water quality management, the system incorporates behavior monitoring, which provides insights into fish feeding patterns, social interactions, and overall well-being. Behavioral changes can indicate stress or health issues, enabling farmers to intervene before problems escalate. Furthermore, the system utilizes machine learning algorithms to analyze collected data, identifying trends and making recommendations for optimal species selection and management practices.

The early detection of diseases is another key feature of the smart aquaculture system. By monitoring behavioral patterns and environmental conditions, the system can identify signs of disease before they lead to outbreaks. This proactive approach not only enhances fish survival rates but also reduces the economic impact of disease on aquaculture operations.

Size monitoring is also integral to the system, allowing farmers to track growth rates and adjust feeding regimes accordingly. Ensuring that fish reach their optimal size in a timely manner is crucial for maximizing productivity and profitability. The user-friendly interface of the smart aquaculture system enables farmers to access real-time data and receive alerts and recommendations, facilitating informed decision-making to improve fish health and productivity.

The integration of technology into aquaculture represents a significant advancement in the industry. By addressing the challenges posed by traditional methods, the smart aquaculture system promotes sustainability and efficiency in fish farming. The potential benefits include optimized resource usage, enhanced fish health, increased productivity, and a reduced environmental footprint.

As the aquaculture industry continues to evolve, the successful implementation of smart technologies will be essential for meeting the growing global demand for seafood while ensuring the long-term viability of fish farming practices. The findings of this study aim to contribute to the ongoing discourse on sustainable aquaculture, highlighting the importance of innovation in addressing the pressing challenges of the industry.

In conclusion, this investigation underscores the critical role that technology can play in transforming aquaculture practices. By leveraging IoT and machine learning, the smart aquaculture system offers a comprehensive solution to the issues faced by traditional fish farming, ultimately contributing to food security and the sustainable production of seafood.

Chapter 2

Review of Literature

Table 2.1: Literature Review

Sr. No	Year	Paper	Methods	Limitations
1	2019	Automatic Recognition of Fish Diseases in Fish Farms?	Introduced a system for detecting fish diseases using IoT and machine vision to improve aquaculture health management.	Validation limited to specific disease scenarios; requires more robust datasets for broader applicability.
2	2019	Using Machine Vision to Estimate Fish Length?	Developed a machine vision method to estimate fish lengths using regional convolutional neural networks, achieving high accuracy in controlled conditions.	Accuracy decreases with extreme image rotations; dependent on controlled imaging environments.
3	2019	Analyzing the Quality of Water and Predicting Suitability?	IoT-based prediction of water quality and its impact on fish farming, integrating real-time monitoring and effective prediction techniques.	High dependency on IoT infrastructure and limited adaptability to diverse aquaculture environments.

Table 2.2: Literature Review (Part 2).

Sr. No	**Year**	**Paper**	**Methods**	**Limitations**
4	2024	Charting the Aquaculture IoT Impact**?**	Highlights the role of IoT in water quality monitoring, feeding optimization, and fish health management in aquaculture.	Requires substantial infrastructure investment; sensor durability issues persist in aquatic environments
5	2022	Tracking Fish Behavior Using Computer Vision**?**	Used YOLO and neural networks to detect and analyze fish behaviors in different scenarios, achieving high accuracy.	Limited dataset diversity; computationally intensive.
6	2024	Smart Pond Water Quality Monitoring (Aquabot System)**?**	IoT-based system for real-time monitoring of water quality and fish farming recommendations, achieving high accuracy.	Setup costs, sensor corrosion, and dependency on consistent data transmission.

2.1 Review of Literature

The literature review undertaken in this study provides a comprehensive examination of seven key papers focusing on the application of IoT, machine vision, and deep learning in aquaculture and fishery management. These papers, published between 2000 and 2024, delve into innovative methodologies that enhance the monitoring, analysis, and efficiency of aquaculture systems and fish behavior studies. By critically analyzing these studies, this review delineates the current state of knowledge, highlights significant findings, and identifies gaps in the broader context of smart aquaculture management.

Paper 1, published in 2019, introduces an IoT-based approach for recognizing fish diseases in aquaculture systems. By integrating machine vision, the paper demonstrates improvements in aquaculture health management. Despite promising results, the study's focus on specific diseases and the limited dataset hinder its broader applicability.

Paper 2, also published in 2019, presents a machine vision system leveraging regional convolutional neural networks to estimate fish lengths from images. This method achieves high accuracy under controlled conditions, making it valuable for ecological research and fisheries management. However, its reliance on controlled imaging environments and reduced accuracy in rotated images highlight its limitations.

Paper 3, also from 2019, examines the use of IoT for monitoring water quality and predicting its suitability for fish farming. The study effectively integrates real-time monitoring and predictive analytics but is constrained by its dependency on IoT infrastructure and limited adaptability to diverse environments.

Paper 4, published in 2022, employs YOLO and neural networks to analyze fish behavior under various scenarios. The study achieves high precision in detecting fish behaviors like feeding and stress responses. However, the limited dataset diversity and high computational requirements restrict its scalability.

Paper 5, published in 2024, investigates the transformative impact of IoT in aquaculture. It highlights applications in water quality monitoring, feeding optimization, and fish health management. While the study underscores the potential for global aquaculture improvements, it also identifies significant challenges, including infrastructure costs and sensor durability.

Paper 6, also from 2024, introduces an IoT-based Aquabot system for smart pond water quality monitoring and fish farming recommendations. This system demonstrates high accuracy (94%) in real-time monitoring and predictive analytics. However, the initial setup cost, sensor corrosion, and dependency on consistent data transmission are notable limitations.

In conclusion, the synthesis of these papers underscores the transformative potential of IoT, machine vision, and deep learning in aquaculture and fisheries management. The studies demonstrate advancements in monitoring, analysis, and automation, but also highlight critical challenges, such as infrastructure requirements, cost-effectiveness, and scalability. This review contributes to a deeper understanding of the current landscape and offers insights for future research and development in smart aquaculture systems.

Chapter 3

Project Vision

The project vision based on this introduction is to develop an innovative and sustainable aquaculture system that ensures optimal growth, efficient resource utilization, and high productivity. By prioritizing water quality, species recommendation, and disease detection, the project aims to support global food security while promoting environmental sustainability and reducing dependency on wild fish stocks. This vision seeks to leverage technology and data-driven solutions for sustainable and efficient aquaculture practices.

3.1 Problem Statement

Aquaculture faces challenges such as suboptimal fish growth due to traditional methods, difficulties in choosing the right fish species, and resource wastage from poor water management. Inadequate disease detection tools increase the risk of outbreaks, which impacts fish health and overall productivity.

3.2 Business Opportunity

This project offers significant business opportunities, including:

1. **Aquaculture Technology Solutions**: Develop IoT-based monitoring systems, au-

tomated feeding tools, and disease detection technologies.

2. **Sustainable Practices**: Provide consulting for eco-friendly aquaculture, species recommendation services, and optimized breeding stock.

3. **Market Expansion**: Supply sustainably farmed seafood to global markets and partner with retail and B2B channels.

4. **Education and Training**: Offer workshops, certifications, and digital courses for aquaculture professionals.

5. **Carbon Credits & ESG**: Enable businesses to offset carbon footprints and appeal to environmentally conscious investors.

These opportunities cater to the rising demand for seafood, sustainable practices, and smart farming technologies, ensuring both profitability and environmental impact.

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3.3 Objectives

The objective of this project is to develop an advanced aquaculture system that includes a fish type classification model, size and growth monitoring, behavior tracking, and disease detection to improve fish farming practices.

The project aims to integrate these modules with sensors and existing systems to create a reliable solution that ensures fish health and productivity. Real-time alerts and a user-friendly web/app interface will be developed to help users monitor fish conditions, receive notifications, and take timely actions.

3.4 Project Scope

The project aims to revolutionize aquaculture through the integration of cutting-edge technologies, with a focus on sustainability, efficiency, and scalability. The scope of the project includes:

3.4.1 Water Quality Monitoring:

Develop IoT-based sensors for real-time monitoring of water parameters like pH, temperature, turbidity, and dissolved oxygen.
Implement predictive analytics to identify and address potential water quality issues.

3.4.2 Species Recommendation

Design machine learning algorithms to recommend fish species best suited to specific water conditions and market demands.
Enable farmers to optimize production by selecting species with high growth rates and adaptability.

3.4.3 Growth Optimization

Introduce automated feeding systems to optimize feed usage, minimize waste, and promote healthy fish growth.
Use AI-powered analytics to track fish growth and adjust farming practices accordingly.

3.4.4 Size Measurement

Utilize machine vision and image processing techniques to measure fish size accurately in real-time.
Provide data for monitoring growth patterns, ensuring timely harvesting, and improving yield predictions.

3.4.5 Sustainability

Promote eco-friendly practices by reducing resource wastage and supporting sustainable aquaculture.
Enhance productivity while minimizing environmental impact.

3.4.6 Efficient Resource Utilization

Integrate energy-efficient solutions such as solar-powered systems for IoT devices.
Utilize data-driven decision-making to maximize resource use and profitability.

3.4.7 Scalability and Accessibility

Design systems that are adaptable to various farm sizes and geographic locations.
Ensure affordability and ease of use for small- to large-scale fish farmers.

By addressing these focus areas, the project aims to enhance productivity, improve profitability, and establish a sustainable aquaculture model to meet the growing global demand for seafood.

3.5 Constraints

3.5.1 Technological Limitations

High setup costs and sensor durability issues in aquatic environments.
Connectivity challenges in remote areas affecting real-time data transmission.

3.5.2 Environmental Factors

Water quality variability due to pollution and climate change.
Potential ecological impacts of intensive aquaculture.

3.5.3 Scalability

Adapting technology for small-scale farms and diverse geographic locations. Operational Costs
Recurring expenses for maintenance and dependence on skilled labor.

3.5.4 Data Accuracy

Risk of sensor errors and challenges in ensuring reliable real-time analytics.

3.5.5 Regulations

Compliance with environmental laws and ethical considerations in farming.

3.6 Stakeholders Description

3.6.1 Stakeholders Summary

The primary stakeholders for this aquaculture project include:

- **Fish Farmers**: Individuals and organizations managing aquaculture operations, seeking improved productivity and reduced costs.
- **Technology Providers**: Companies offering IoT devices, sensors, and software solutions to enhance aquaculture efficiency.
- **Regulatory Bodies**: Government and environmental agencies ensuring compliance with regulations and promoting sustainability.
- **Investors**: Individuals or institutions funding aquaculture technology development and deployment.
- **End Consumers**: Customers demanding sustainably sourced, high-quality seafood.

3.6.2 3.6.2 Key High-Level Goals and Problems of Stakeholders

- **Fish Farmers**
  - **Goals**: Maximize yield, reduce costs, and ensure fish health.
  - **Problems**: High setup costs, lack of technical expertise, and risks of disease or poor water quality.
- **Technology Providers**
  - **Goals**: Deliver innovative, scalable, and affordable solutions.
  - **Problems**: Sensor durability, connectivity issues, and limited adoption by small-scale farmers.
- **Regulatory Bodies**
  - **Goals**: Ensure environmental sustainability and compliance with farming standards.
  - **Problems**: Limited monitoring resources and enforcement capabilities.
- **Investors**
  - **Goals**: Achieve returns on investments through scalable solutions.
  - **Problems**: High initial costs and market adoption risks.
- **End Consumers**
  - **Goals**: Access high-quality, sustainably sourced seafood.
  - **Problems**: Lack of transparency about sourcing and sustainability practices.

Chapter 4

Software Requirements Specifications

This chapter will have the functional and non functional requirements of the project.

4.1 List of Features

- Real-time water quality monitoring.
- Automated species recommendation.
- Growth tracking and size measurement.
- Resource optimization through IoT-based solutions.
- User-friendly dashboards for data visualization.

4.2 Functional Requirements

- The system must monitor water parameters like pH, temperature, and turbidity in real time.
- Provide automated fish species recommendations based on water quality.
- Measure and track fish growth using machine vision techniques.

- Generate actionable alerts for suboptimal conditions.
- Offer an intuitive web and mobile interface for users.

4.3 Quality Attributes

- **Reliability**: Ensure continuous operation with minimal downtime.
- **Scalability**: Support farms of various sizes.
- **Accuracy**: Deliver precise measurements and recommendations.
- **Usability**: Maintain a user-friendly interface for non-technical users.
- **Efficiency**: Optimize resource usage, minimizing waste and energy consumption.

4.4 Non-Functional Requirements

- The system must operate on low power consumption.
- Ensure compatibility with common IoT devices and sensors.
- Provide data security through encryption.
- Maintain response time within 2 seconds for real-time alerts.
- Support at least 500 concurrent users.

4.5 Use Cases/ Use Case Diagram

1. **View Information**
    - **Actors**: User
    - **Description**: Allows users to access fish health, water parameters, and movement data.

- **Extensions**: Includes ‘Check Fish Disease‘.

2. **Check Fish Disease**
   - **Actors**: User
   - **Description**: Checks for fish diseases using captured data from ‘Disease Detection‘.

3. **Capture Images**
   - **Actors**: Camera
   - **Description**: Captures images for ‘Fish Size Monitor‘ and ‘Disease Detection‘.

4. **Fish Size Monitor**
   - **Actors**: Camera
   - **Description**: Measures fish size using image data to monitor growth.

5. **Capture Videos**
   - **Actors**: Camera
   - **Description**: Captures videos for ‘Fish Movement Monitoring‘ and ‘Capture Parameters‘.

6. **Fish Movement Monitoring**
   - **Actors**: Camera, User
   - **Description**: Tracks fish movement and behavior using video data.

7. **Capture Parameters**
   - **Actors**: Sensors
   - **Description**: Collects water data (pH, temperature, turbidity) for analysis.

8. **Fish Species Recommendation**
   - **Actors**: Sensors, User

- **Description**: Recommends fish species based on water quality parameters.

9. **Water Monitoring**

- **Actors**: Sensors
- **Description**: Monitors water quality and raises alerts for deviations.

4.5.1 Use Case Diagram

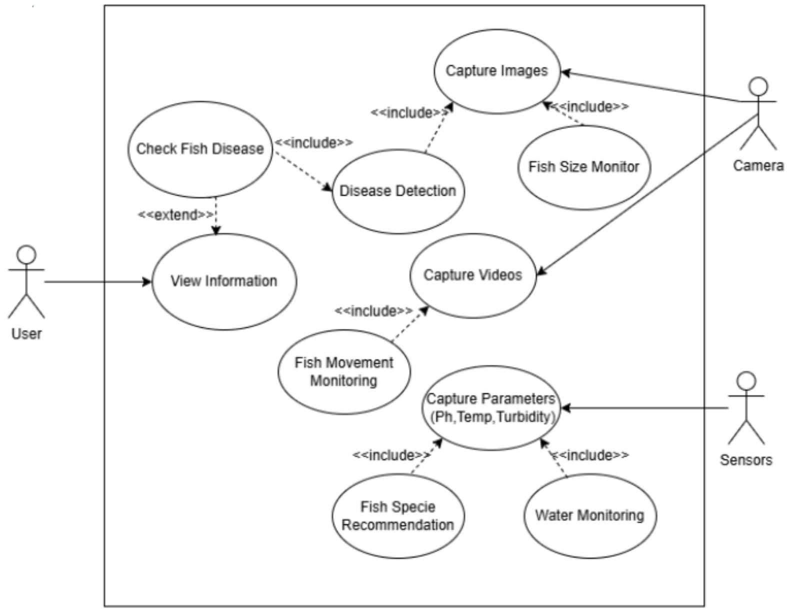

Figure 4.1: Use Case Diagram

4.6 Architecture Diagram

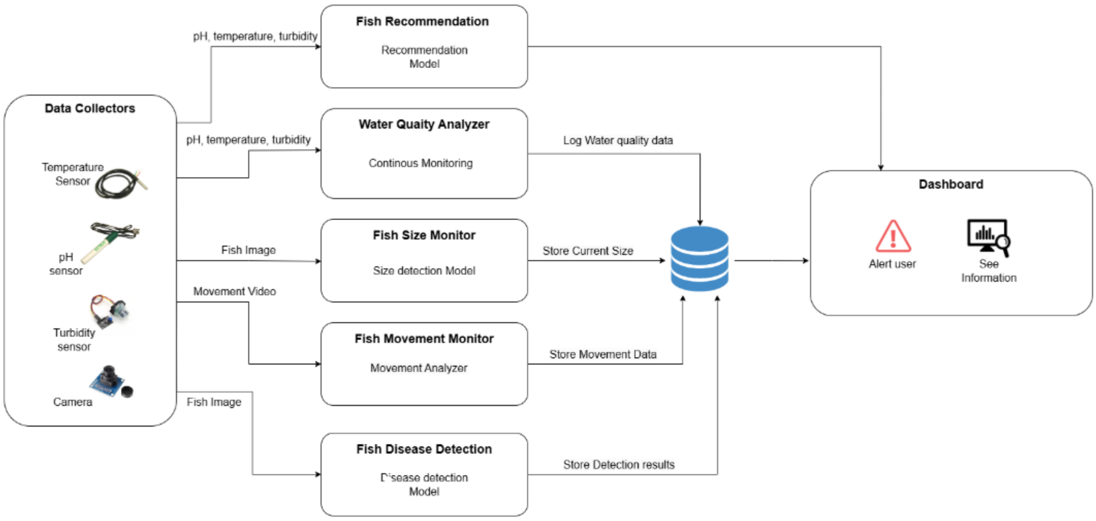

Figure 4.2: Architecture Diagram

4.7 UI Screens

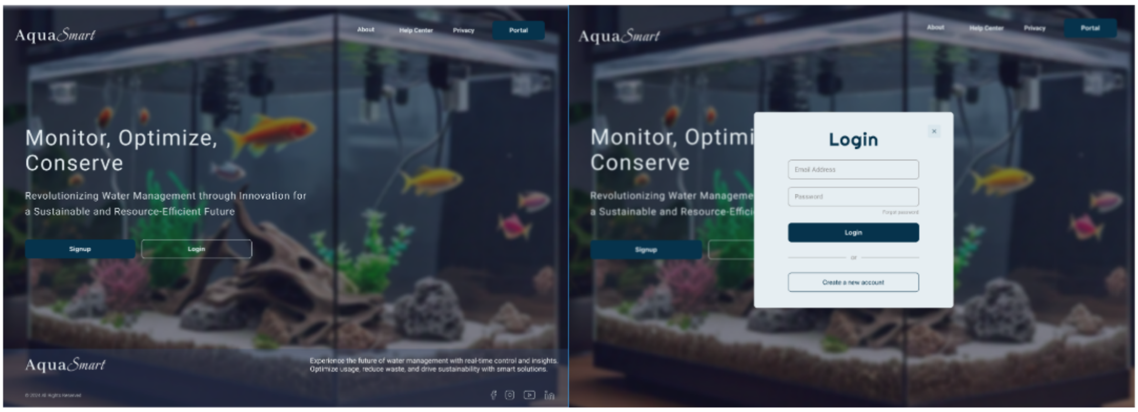

Figure 4.3: Login Page

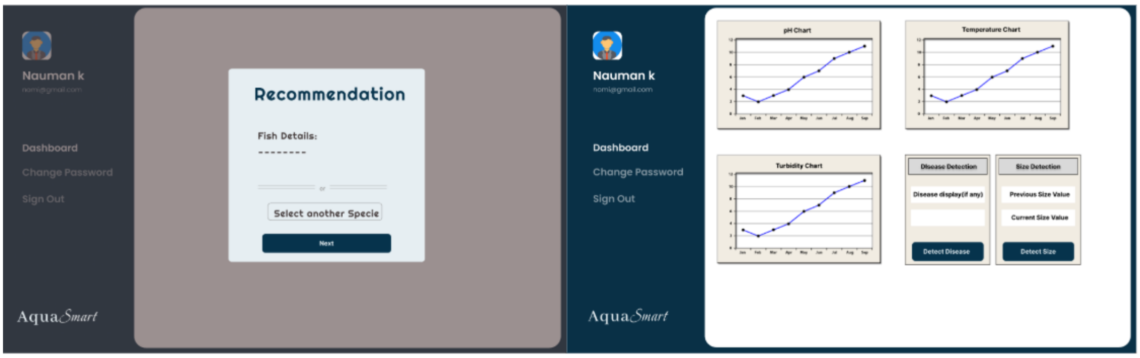

Figure 4.4: Dashboard

Chapter 5

Iteration Plan

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5.1 FYP 1 Iteration Plan

- **Start of FYP 1**
  - **Timeline**: 10 August
  - **Description**: Official commencement of the Final Year Project with initial discussions and planning.
- **Project Proposal**
  - **Timeline**: 25 August to 31 August
  - **Description**: Develop the project proposal, outlining the objectives, scope, methodology, and expected outcomes.
- **Project Proposal Defense**
  - **Timeline**: 1 September to 8 September
  - **Description**: Present the project proposal to the supervisor and committee for approval and feedback.

- **Literature Review**
  - **Timeline**: 25 August to 31 October
  - **Description**: Conduct an in-depth review of existing research related to IoT-based aquaculture monitoring systems, machine learning models, and system architectures.
- **Data Collection Requirements & System Design**
  - **Timeline**: 8 September to 20 October
  - **Description**: Define system requirements and collect relevant datasets for water quality monitoring and fish classification.
- **Developing Fish Type Classification Model**
  - **Timeline**: 20 September to 15 October
  - **Description**: Build a machine learning model to classify fish types based on water parameters and captured images.
- **Prototype of Growth Optimization Model**
  - **Timeline**: 10 October to 31 October
  - **Description**: Develop a prototype model for tracking fish growth and optimizing feeding schedules.
- **Testing Initial Algorithm**
  - **Timeline**: 25 October to 10 November
  - **Description**: Test the initial algorithm for water monitoring and fish size measurement.
- **Documentation**
  - **Timeline**: 20 November to 04 December
  - **Description**: Compile all project-related materials, including the literature review, system design, and testing results, into a comprehensive report.

- **End of FYP 1**
  - **Timeline**: 04 December
  - **Description**: Conclude FYP 1 with a formal submission of the project report and deliverables.

5.1.1 Timeline Visualization

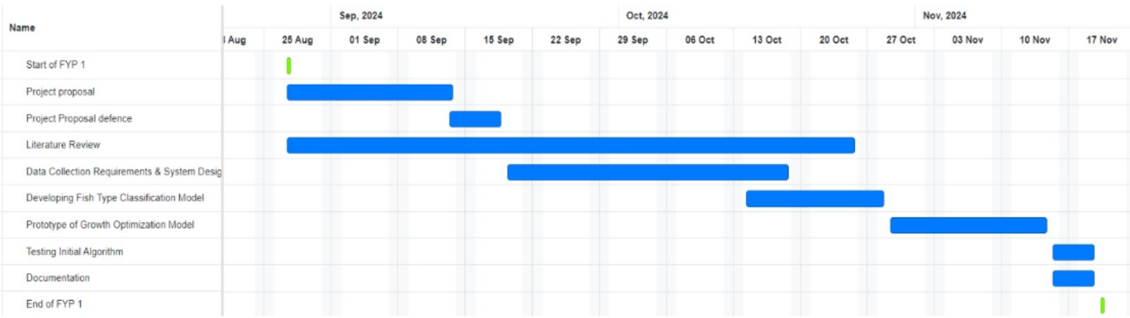

Figure 5.1: FYP 1 Iteration Plan Timeline