Faculty of Electronic & Computer Technology and Engineering

A COMPUTER VISION - BASED FISH MONITORING SYSTEM IN AQUACULTURE TECHNOLOGY

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Bachelor of Electronics Engineering Technology with Honours

2024

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A project report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Electronics Engineering Technology with Honours

Faculty of Electronic & Computer Technology and Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2024

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI TEKNOLOGI KEJUTERAAN ELEKTRIK DAN ELEKTRONIK

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : A Computer Vision-Based Fish Monitoring System In Aquaculture Technology

Sesi Pengajian : Semester 1 2023/2024

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ABSTRACT

A computer vision-based fish monitoring system is a system that uses computer vision techniques to automatically detect, track, and analyze fish in aquatic environments. The system includes underwater cameras that capture images or videos of fish, which are then analyzed by computer vision algorithms to extract relevant information about the fish .Fish populations are being threatened by overfishing in the fishing industry, which could have major ramifications for food security, biodiversity, and the lives of millions of people. Furthermore, it can be challenging to manage fisheries sustainably and safeguard vulnerable species due to the time-consuming, and labor-intensive.This knowledge, may be used to replace traditional techniques such as direct observation, which are impractical or affect the fish behavior, in task such as aquarium and fish farm management or fish way evaluation. The main objective for this project are to design a fish monitoring system based on computer vision platform determining fish and water quality.Next, to evaluate the performance of the fish monitoring platform accuracy using statistical approach. The result shows the system were able to detect and traking the fish also display the water quality. The fish monitoring system has the potential to revolutionize fish monitoring practices, enabling more accurate and efficient data collection compared to traditional manual methods.

ABSTRAK

Sistem pemantauan ikan berasaskan penglihatan komputer ialah sistem yang menggunakan teknik penglihatan komputer untuk mengesan, menjejak dan menganalisis ikan secara automatik dalam persekitaran akuatik. Sistem ini termasuk kamera dalam air yang menangkap imej atau video ikan, yang kemudiannya dianalisis oleh algoritma penglihatan komputer untuk mengekstrak maklumat yang berkaitan tentang ikan .Populasi ikan sedang diancam oleh penangkapan ikan yang berlebihan dalam industri perikanan, yang boleh membawa kesan besar terhadap keselamatan makanan, biodiversiti, dan kehidupan berjuta-juta orang. Tambahan pula, adalah mencabar untuk mengurus perikanan secara mampan dan melindungi spesies yang terdedah kerana memakan masa, dan intensif buruh. Pengetahuan ini, boleh digunakan untuk menggantikan teknik tradisional seperti pemerhatian langsung, yang tidak praktikal atau menjejaskan tingkah laku ikan, dalam tugas seperti pengurusan akuarium dan ladang ikan atau penilaian cara ikan. Objektif utama projek ini adalah untuk mereka bentuk sistem pemantauan ikan berdasarkan platform penglihatan komputer yang menentukan kualiti ikan dan air. Seterusnya, untuk menilai prestasi ketepatan platform pemantauan ikan menggunakan pendekatan statistik. Hasilnya menunjukkan sistem dapat mengesan dan mengesan ikan juga memaparkan kualiti air. Sistem pemantauan ikan berpotensi untuk merevolusikan amalan pemantauan ikan, membolehkan pengumpulan data yang lebih tepat dan cekap berbanding kaedah manual tradisional.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my gratitude to my supervisor, IR. TS. DR. Ahmad Fauzan Bin Kadmin for their precious guidance, words of wisdom and patient throughout this project.

I am also indebted to Universiti Teknikal Malaysia Melaka (UTeM) and my parent for the financial support which enables me to accomplish the project. Not forgetting my fellow colleague for the willingness of sharing his thoughts and ideas regarding the project.

My highest appreciation goes to my parents, parents in-law, and family members for their love and prayer during the period of my study. An honourable mention also goes to supervisor for all the motivation and understanding.

Finally, I would like to thank all the classmates, the Faculty members, as well as other individuals who are not listed here for being co-operative and helpful.

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CHAPTER 1

INTRODUCTION

1.0 Project Background

The Computer Vision-Based Fish Monitoring System is a project aimed at developing a system that uses computer vision technology to monitor fish populations in aquatic environments. The system will consist of cameras that are placed in strategic locations within the aquatic environment. The cameras will capture video footage of the fish and send the footage to a computer system that will analyze the footage using computer vision algorithms. The algorithms will be designed to identify the fish behaviour.

The project has significant implications for the management of aquatic environments.. The Computer Vision-Based Fish Monitoring System aims to provide a efficient alternative methods, allowing for more accurate and timely monitoring of fishes. This could help to improve the management and conservation of aquatic environments, as well as provide valuable data for scientific research.

1.2 Societal/Global Issue

Overfishing is a serious global issue that threatens the sustainability of marine ecosystems and the livelihoods of millions of people who depend on fish for food and income. Overfishing refers to the practice of catching more fish than can be naturally replenished in a particular area, which can lead to a decline in fish populations and ecological imbalances. By promoting sustainable fishing practices, the system can help to prevent overfishing and ensure that fish populations are able to recover and reproduce. This can help to ensure a consistent and sustainable supply of fish for food and income, particularly in developing countries where fish is a vital source of protein and nutrition. Figure 1.1 demonstrate that fish populations essential for food and jobs have crashed by 50% in the last 4 decades.

Other than that, A fish monitoring system can help in fish security by ensuring that fish populations are sustainably managed, which can help to ensure a reliable supply of fish for food and income. The system can provide real-time data on fish populations, which can inform decisions about fishing quotas, habitat protection, and conservation efforts.

Figure 1.1 The Decrements Of Fish Population In Last 4 Decade

1.3 Problem Statement

The problem at hand is the need to develop a more effective and precise technique for fish population monitoring to support sustainable fisheries management and conservation activities. The fishing industry plays a crucial role in providing food security, supporting livelihoods, and contributing to the economy. Overfishing is a critical issue that poses significant threats to fish populations, marine ecosystems, and global food security. It occurs when the rate of fishing exceeds the reproductive capacity of fish species, leading to a decline in population sizes and potentially causing irreversible damage to marine ecosystems.

Current fish farming practices commonly rely on manual observation, which is not scalable or efficient enough to assess and manage fish populations on a larger scale. Another method is by sonar systems which can detect fish presence and population density but lack the ability to identify species or track behavior. Passive Acoustic Monitoring (PAM) captures fish sounds but has limitations in providing a comprehensive understanding of populations and addressing overfishing challenges. Therefore, a more effective and precise technique for fish population monitoring is needed to support sustainable fisheries management and conservation efforts.Figure 1.2 shows how PAM works in detecting fish population.

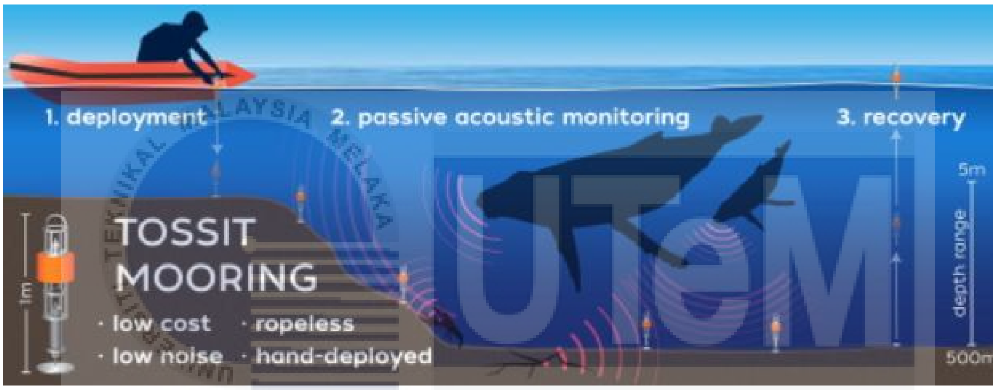

Figure 1.2 Passive Acoustic Monitoring (PAM)

1.4 Project Objective

The objectives of the project include:

a. To design a fish monitoring system based on computer vision platform determining fish and water quality.
b. To evaluate the performance of the fish monitoring platform accuracy using statistical approach.

1.5 Scope of Work

The scope of this project are as follows:

a. Determine the data requirements for the monitoring system, such as video footage or images of fish.
b. Implement computer vision algorithms to detect fish in the collected images or video footage.
c. Implement behavioral analysis algorithms to extract meaningful information.
d. Monitor the system's performance over time and address based on the dish and water quality.

1.6 Contribution of the project

A computer vision-based fish monitoring system can contribute to various fields, such as fisheries management, aquatic ecology, and aquaculture. A computer vision-based fish monitoring system can help to automate tasks in aquaculture, such as water quality control, monitoring fish health, and tracking fish behavior. This can lead to increased efficiency and reduced labor costs for aquaculture operators. Other than that , the development of a computer vision-based fish monitoring system can also contribute to advancements in computer vision technology, particularly in the areas of object detection, tracking, and analysis of the fishes.A computer vision-based fish monitoring system can provide more accurate and efficient data on fish populations in natural water bodies. This information can help fisheries managers and conservationists better understand the abundance and decrease the potential of fish quality.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The purpose of this literature review is to evaluate the current state of knowledge on computer-based fish monitoring systems. Specifically, this review will mainly focus on methods that previous research used, their problem statement, and their effectiveness in monitoring fish behavior. This review will also explore the various technologies used in these systems, such as cameras, sensors, and algorithms architecture.

2.1.1 Fish Market

The fish farming market in Malaysia has been growing steadily over the years, driven by factors such as increasing demand for seafood, rising population, and declining wild fish stocks. Malaysia is blessed with abundant water resources, including rivers, lakes, and coastal areas, which provide a conducive environment for fish farming.

Referring to figure 2.1, it shows the Gross Domestic Product (GDP) fishing industry in Malaysia from 2016 until 2021.In 2021, GDP from the entire Malaysian fishing industry was 11.22 billion Malaysian ringgit. There has been a decrease in the GDP from fishing industry in the country as compared to the previous years. On the other hand , table 2.1 shows the export and import of fishery products of Malaysia by quantity and value from 2015 until 2019. the data show that there is increment of import and export for each year and reach the highest value in 2019.

Overall, the fish farming market in Malaysia has significant growth potential, given the country's favorable natural resources and government support. However, challenges such as environmental concerns, disease outbreaks, and market volatility also exist and must be addressed to ensure the long-term sustainability of the industry.

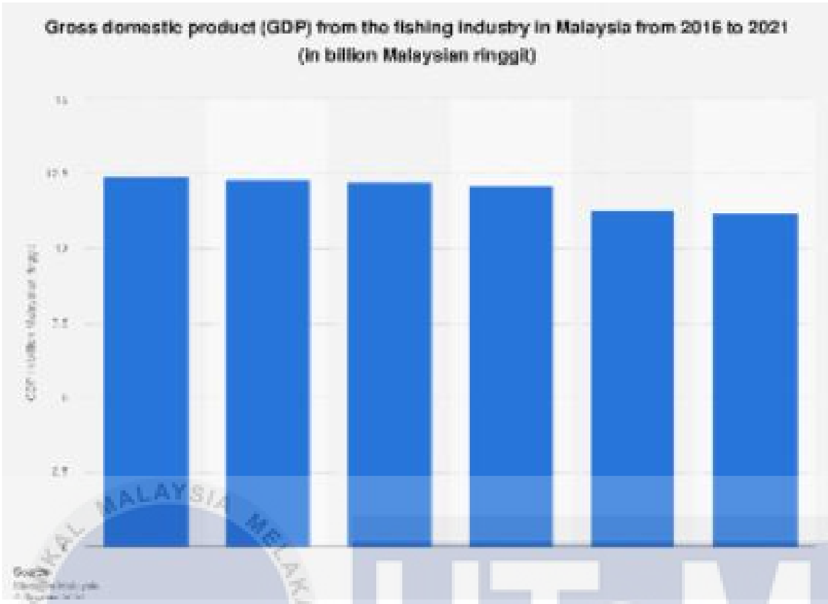

Figure 2.1 Gross Domestic Product Fishing Industry In Malaysia

Table 2.1 Export And Import Of Fishery Products Of Malaysia By Quantity And Value

Year	Export		Import	
	Quantity (MT)	Value (US$ 1,000)	Quantity (MT)	Value (US$ 1,000)
2019	298,955	900,446	457,364	1,154,374
2018	263,616	764,999	431,308	1,066,537
2017	237,516	720,688	425,901	1,003,884
2016	296,626	712,732	408,251	955,990
2015	252,748	688,356	424,316	948,710

2.1.2 Fish Farming

Aquaculture, often known as fish farming, has been practised for a very long time. There is evidence that the Chinese, Romans, and ancient Egyptians all cultivated fish in ponds for nourishment. Fish ponds were constructed in ancient Rome for the aim of raising fish for consumption in banquets and as a medicine. Fish farming has been practised constantly in China since the Tang Dynasty (618-907 AD), when it was first noted. Fish farming is now a worldwide industry, with production taking place in numerous nations. With the use of cutting-edge technologies like recirculating aquaculture systems, genetic selection, and alternative feeding, the sector has become more sophisticated. Fish farming is projected to become more crucial in supplying the world's food needs as the demand for seafood rises, relieving pressure on wild fish supplies in the process

In Malaysia, fish farming is predominantly carried out in freshwater systems such as ponds, tanks, and cages, as well as in brackish and marine environments along the coasts. The country's aquaculture sector is mainly focused on certain species such as seaweed, grouper, tilapia, and catfish. The table 2.2 shows the production of major group from aquaculture in Malaysia .

Table 2.2 Production Of Species From Aquaculture Of Malaysia By Quantity

Major species/group	2019	2018	2017	2016	2015
Seaweeds	188,110	174,083	202,966	205,989	260,760
Shrimps/prawns	53,606	46,126	46,075	43,556	52,838
Catfishes	47,533	53,400	56,877	55,120	64,585
Tilapias	36,159	31,766	32,526	36,997	36,299
Barramundi	17,264	21,248	30,217	15,025	29,133
Molluscs	16,608	18,350	16,196	12,226	18,237

2.2 Traditional Fish Monitoring System

Fish populations and their habitats are often manually observed in traditional fish monitoring systems. Fish behaviour can be observed visually, water quality can be measured using portable metres, and fish populations can be periodically sampled with nets or other fishing equipment.A traditional monitoring system in a fish farm, for instance, would include human observations of fish behaviour and health as well as checking the water quality with portable metres to detect variables like temperature, pH, and dissolved oxygen levels. To gauge the quantity and health of the fish population, periodic sampling of fish populations using nets or other fishing gear may also be carried out.

In natural aquatic ecosystems, traditional monitoring systems may involve periodic sampling of fish populations using nets or other fishing gear, as well as monitoring water quality parameters such as temperature, pH, dissolved oxygen, and nutrient levels. This can provide information on the health of the fish population and the ecosystem as a whole. However, traditional fish monitoring systems can be labor-intensive and time-consuming, and may not provide real-time data on fish behavior and habitat conditions [12]. They also may not be able to provide continuous monitoring over long periods of time, which can make it difficult to detect changes in the fish population or habitat conditions.Figure 2.2 show that the fisherman were manually survey the fish by using net.

Figure 2.2 Manual Survey Of Fish

2.3 Modern Fish Monitoring System

Modern fish monitoring systems are increasingly using computer vision technologies. Fish can be automatically identified and tracked using computer vision, which analyses video material using algorithms and machine learning techniques. By replacing the requirement for manual monitoring techniques, this technology can provide more precise and effective data on fish populations and their behavior [27].

Figure 2.3 is one example of modern fish monitoring system .The Pacific Northwest National Laboratory's FishCam system is one instance of computer vision technology being utilised for fish monitoring. FishCam records video of fish swimming over a certain area using many cameras installed on underwater structures. Researchers can then collect information on fish behaviour and migration patterns from the camera footage by utilising computer vision algorithms to identify and track specific fish.

Figure 2.3 The FishCam system

The OpenCV Fish Tracker, which use the OpenCV computer vision library to track fish in real-time, is another instance of computer vision technology being utilised for fish monitoring. Both regulated surroundings, like fish tanks, and natural settings, such rivers and lakes, can make use of the system. Researchers can obtain information on fish behaviour through the OpenCV Fish Tracker, including information on swimming direction, speed, and proximity to other fish. Figure 2.4 are one of a example how fish tracking using OpenCV.

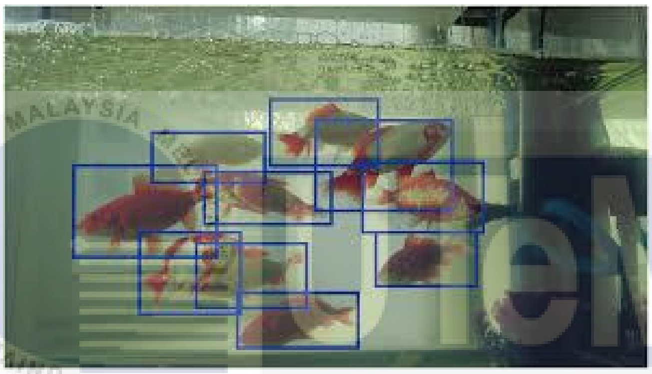

Figure 2.4 Example of Fish Tracking Using OpenCV

2.4 Water Quality

Water quality is an important factor to consider in fish monitoring systems. Poor water quality can negatively impact fish health and can even lead to death. Therefore, it is essential to regularly monitor water quality parameters to ensure a healthy environment for fish. Some of the key water quality parameters that should be monitored in fish monitoring systems include temperature, dissolved oxygen, pH, ammonia, nitrate, nitrite, total alkalinity, and turbidity. These parameters can be measured using various instruments such as probes, sensors, and meters.

2.4.1 Temperature

According to [6] , it states that the temperature of the aquarium water is one of the most important parameters that the owner must monitor when keeping fish. The owner must ensure that the aquarium water temperature does not exceed the minimum or maximum thresholds. Fish or other living things in the aquarium can become stressed if the water temperature is too low or too high, which can result in death. Fluctuating water temperature out of the ideal range can also impact the fish's metabolism and will lead to death. The optimal water temperature for freshwater fish keeping is between 24 and 28 degrees Celsius

2.4.2 pH Level

pH level is an important parameter to monitor in a fish monitoring system, as it can have a significant impact on fish health and survival. A pH sensor can be used to measure the pH level of the water in the fish tank or pond, and the data can be collected and processed using a microcontroller.A pH sensor works by measuring the concentration of hydrogen ions in the water, which is directly related to the pH level. Referenced to Figure 2.5 and [4] the ideal pH range for a fish-friendly ecosystem is between pH 6.5 and pH 7.5. Electrodes are utilized in a pH sensor's basic operating system to find H^+ ions in liquids.

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The pH level in the aquarium is crucial for guppies since it should be maintained between 6.8 and 7.8, according to research on Aquarium Monitoring System for Guppy Fish . In the experiment , the two forms of guppy food used in this study are pellet and Baby Brine Shrimp (BBS) type. With BBS, the pH level falls below 6.8 during the first two days, yet the guppy is still alive because the pH levels are still somewhat normal. The water filter had been off for two nights in a row when the pH level dropped. While using a pallet, it only consistently varies between 0.2 and 0.3. The experiment's pH reading is the one that is best suitable for guppies breeding [5].

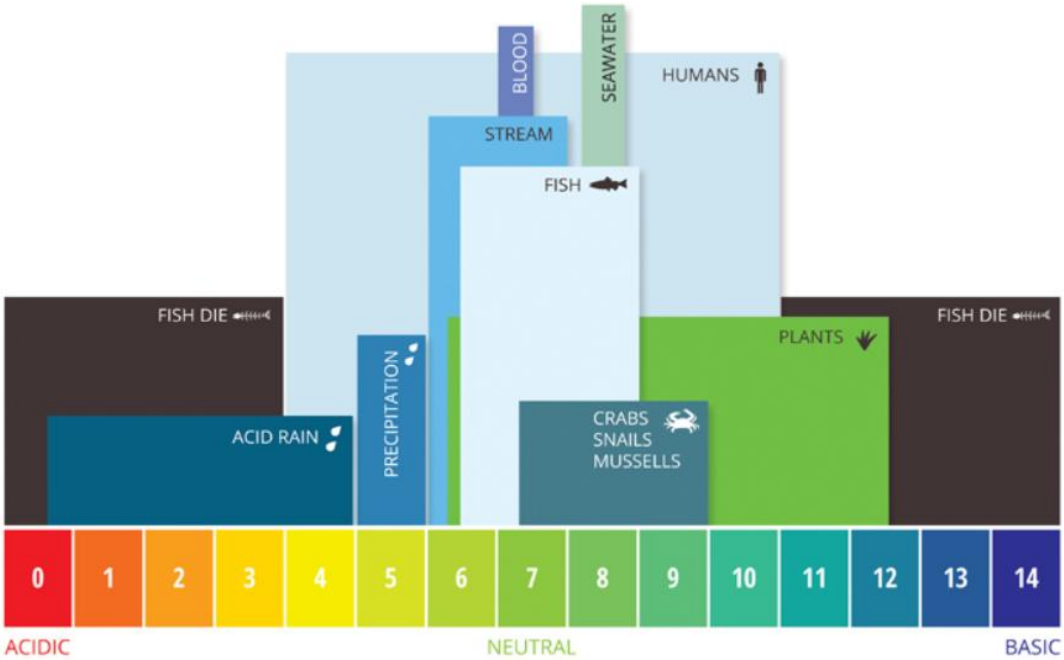


Figure 2.5 Relationship between pH level and Fish

2.4.3 Microcontroller

A microcontroller can be used in a fish monitoring system to collect and process data from sensors and other devices. The microcontroller can act as the brain of the monitoring system, controlling the operation of sensors, storing data, and transmitting data to a central location for analysis. The system can be used to monitor different parameters . Some of the popular microcontrollers used by previous paper is Arduino MEGA 2560, Raspberry Pi, and ESP8266. In the research of loT-based Aquarium Monitoring System for Guppy Fish Habitats ,The system uses Arduino Uno as a microcontroller that is equipped with a waterproof temperature sensor to detect temperature levels in the water, a turbidity sensor to check on turbidity, and a pH sensor to read the pH level of the water inside the aquarium [5].

Typically, a microcontroller serves the following three basic purposes:

- Receive input from a sensor, a human, or other source;
- store and convert this input into a series of actions; etc.
- Apply the data that has been processed to other actions that have an output.

2.5 Fish Behavior

A fish monitoring system must pay close attention to fish behaviour since it can reveal information about the health and wellbeing of fish populations and their surroundings. Fish farmers or researchers may be able to take prompt and appropriate action to address difficulties if they notice changes in fish behaviour, which may be an indication of a range of problems, including changes in water quality, disease, or predation.

2.5.1 Fish Behavior On Difference Environment

The fish behavior detection is extremely important for farmers to get information on life indicators of fish, which could be useful to prevent disease outbreaks, predict water quality changes, and improve fish welfare [9]. However, conventional fish disease detection does not meet real-time detection requirements and could have an irreversible influence on fish. Additionally, abnormal detection based on school behavior does not allow for the detection of early abnormal behavior in single fish. To solve this problem, a novel method of abnormal behavior detection based on image fusion was proposed. Firstly, the outline information of the moving object was extracted based on image processing technology. Secondly, the position information of the fish image was enhanced using mosaic image fusion. Finally, bidirectional feature pyramid network, coordinate attention block, and spatial pyramid pooling were added to YOLOv5, which was named BCS-YOLOv5. And compared with the other two typical models, the BCS-YOLOv5 based image fusion achieved the best accuracy with an average accuracy of 96.69% at 45 frames per second in four typical behavior datasets. The proposed method not only improves the extraction of location information but also quantitatively detects similar anomalous behavior, which meets the demand for real-time detection of fish abnormal behavior in aquaculture.

In their experiment , it contain 4 different fish status which is normal , disease , pH and hypoxia. The table 2.3 shows the relationship between environmental and fish behavior. Based from figure 2.6 , they found out when the disease occurred, the fish would lose balance. One phenomenon was that the fish's body was lying flat on the bottom of the pool while swimming. The other was that the fish's head was down, its tail was up, and it appeared to float on the surface by the its abdomen, but the fish's body would rarely appear perpendicular to the surface of the water.

When the pH of the water quality changed, the fish tilted while swimming, and with the extension of time, the fish's body gradually turned upward, and finally the fish's head and tail turned perpendicular to the water surface. When the fish were deprived of oxygen, they swam along the walls of the pool and they appeared to float on their heads. The experiment captured behavioral video data for 7 days consecutively [9].

Table 2.3 The relationship between environmental changes and abnormal behavior fish

Status	**Water Temperature**	**Dissolved Oxygen**	**pH**	**Total Ammonia Nitrogen**
Normal	22±0.5C°	6.2 ± 0.3mg/L	7.7 ± 0.2	<0.6mg/L
Disease	22±0.5C°	6.2 ± 0.3mg/L	7.7 ± 0.2	<0.6mg/L
pH	22±0.5C°	6.2 ± 0.3mg/L	5.44 - 5.60	<0.6mg/L
Hypoxia	22±0.5C°	2.78 - 3.28mg/L	7.7 ± 0.2	<0.6mg/L

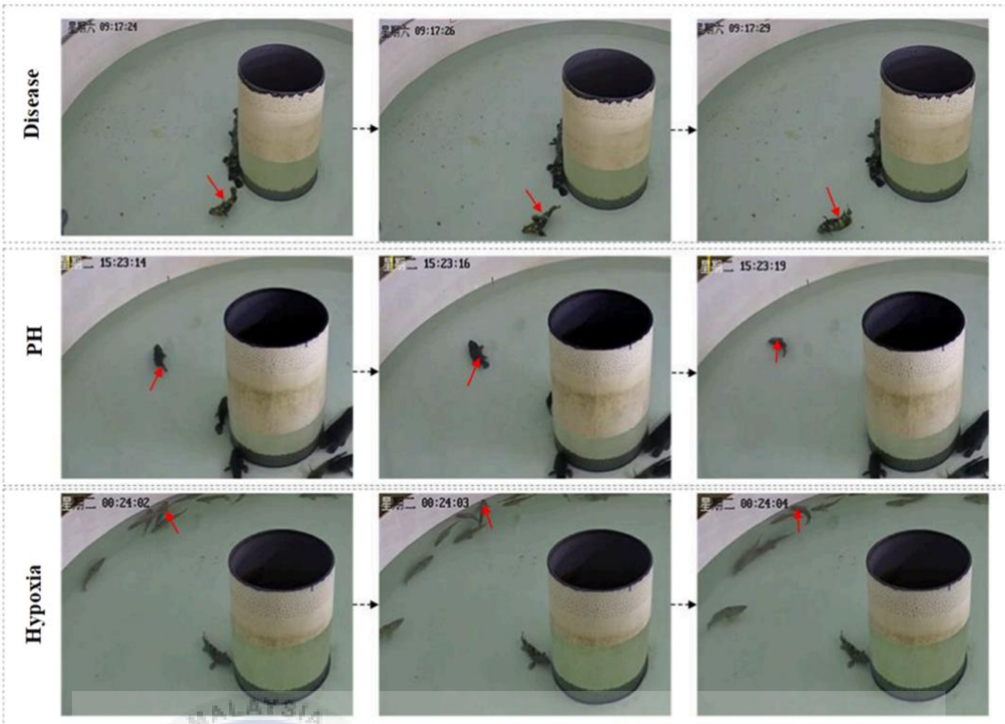


Figure 2.6 Fish behavior on different water condition

2.5.2 Monitoring Fish Stress Based On Behavioral And Physiological Responses

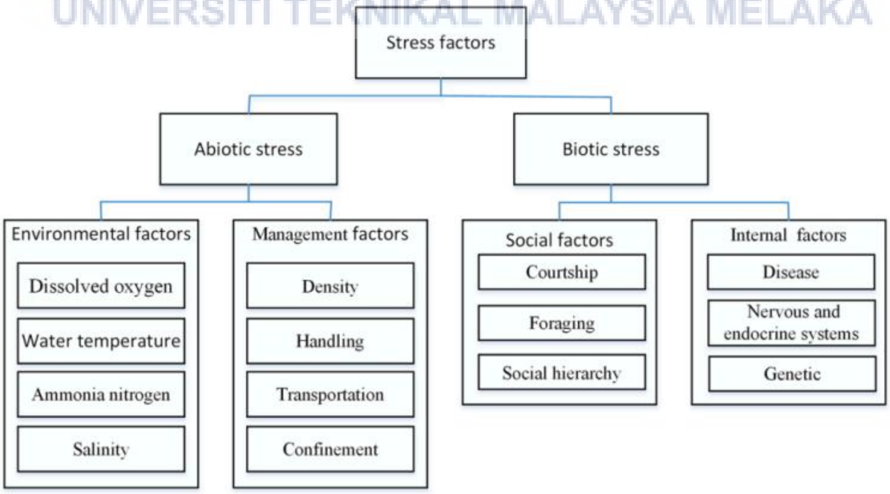


Figure 2.7 Stress factors in aquaculture

As seen in [13] , changes in swimming, foraging, aggression, endocrine levels (including cortisol and blood glucose), cardiopulmonary function, and body colour are among the behavioural and physiological reactions of stressed fish to environmental, aquaculture management, and biological factors. Figure 2.8 summarises the stress behaviour in two categories—abiotic stress and biotic stress. The previous researcher identified stress behaviour in the work by focusing primarily on three principles, including abnormal behaviour, which includes the detection of irregular swimming, trajectory, and physiological activity. The average swimming speed, turning angle, and height of the fish above the bottom from video images were used to assess the health of the fish and analyse the stress in irregular swimming. Additionally, it claims to be effective at aberrant trajectory detection. One of the most efficient and understandable techniques for examining anomalous behaviour is trajectory analysis. In 2D tracking, fish trajectories are typically viewed as point motion in a plane, which is inadequate to capture the depth of the fish in a 3D environment. Fish under stress display a variety of modifications to their outward bodily behaviours. On the physiological side, indications for fish stress and abnormal state have traditionally included body colour, tail-beat frequency, and ventilation frequency. Table 2.4 provides a summary of Daoliang L researches .

Table 2.4 Summary of machine vision - based method

Stress Response	**Principle**	**Species**	**Results**	**Advantage**	**Disadvantages**
Movement patterns	Swimming speed , direction	Rainbow Trout	Swimming Speeds :±1 standard error	High correlation	Lower computational efficiency
Physiological activity	Respiratory rhythms	Medaka	Recognition rate : 99%	Realtime,intuitive	Need to solve the occlusion
Other	Body color	Triostegus	Fish with color pattern is more easy to detected	Intuitive	Low correlation

2.3.3 Fish Growth Rate

According to [26] , the stocking density was changed to a very intensive (320 fish/decimal) aquaculture system in order to more precisely accomplish the desired result. It is crucial to estimate the amount of feed needed in terms of the percentage increase in size and weight at a specific growth stage in relation to time (SGR). Since the initial and final weights are taken into account in the commonly used SGR calculation equation, the outcome is not precise enough to comprehend the growth of fish in the intermediary stages . As a result, it is expected that the development of a relationship between water quality measures and the growth of fish at various stages in relation to intensive farming would be successful. The purpose of the study was to evaluate tilapia development and production while determining the specific growth rate (SGR) of tilapia with a focus on several intermediate sample phases. The study was conducted in tanks feeding with sinking and floating feed in an intense aquaculture system. Additionally, this research sought to quickly increase tilapia production by focusing on cultural techniques. As a result, this method of intense fish culture will enable marginal fish farmers to produce a large amount of fish while still making the projected earnings from a little plot of land [26].

2.4 Monitoring Framework

2.4.1 Image Per-Processing

To make the experimental dataset more diverse and representative, frames with different behaviors caused by states such as disease, normality, hypoxia, and pH were selected from our video sequences. A total of 5443 images were obtained through manual selection, of which 80 % of the data were used for training and 20 % for validation and testing. In manual labeling, fish in different postures were labeled as the same category of "behavior", such as disease, oxygen, normal, and pH, with each of the four categories representing one behavior . We used labeling software (Windows version) as a tool to make fish body labels manually. By applying data augmentation technology, the problem of the large amount of labeled data required for training deep learning models as well as improving the generalization ability and robustness of the algorithm is solved [9].

2.4.2 Mosaic image fusion

Image fusion is the combination of images or image sequences of a specific scene at a particular time to produce a fused image that is more suitable for human visual perception or further computer processing and analysis [9]. Pixel-level fusion generally requires the original images to be spatially aligned with the same resolution accurately. To reduce the impact of the fusion on the colour and texture of the original image, and only add the motion contour in the formation of the moving target, we proposed a mosaic of pixel-level fusion. Mosaic refers to a CutMix data enhancement, which uses four images for splicing. The beta distribution is used in Mosaic, when α =1.5, β =1.5, and $\times$ =0.5 is selected, at which point a fusion probability B of 50 % for the two images is the best result for fusion. In contrast, considering that only the contour information of the Gaussian motion map is needed for this experiment, we set B =0.9 to reduce the effect of the Gaussian map on the original map. Figure 2.3 shows the process of a combination of Gaussian extraction and image fusion process.

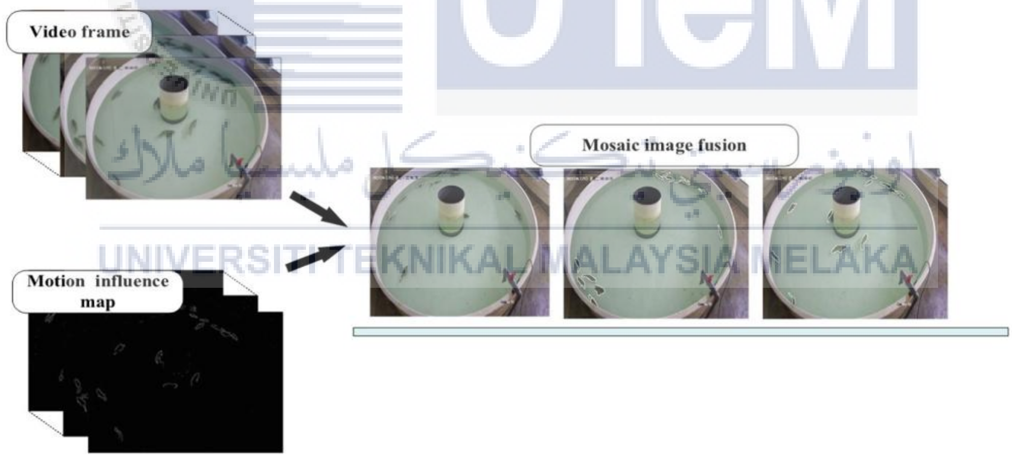


Figure 2.8 Illustration of the process of mixture Gaussian extraction of motion contour information and image fusion process

2.4.3 Proposed Method To Identify Abnormal Fish

To required the data, they used mosaic image fusion where Image fusion is the combination of images or image sequences of a specific scene at a particular time to produce a fused image that is more suitable for human visual perception or further computer processing and analysis.In this study, a YOLOv5-based network framework called BCSYOLOv5 was presented and used for fish abnormal behavior detection. The structure of the BCS-YOLOv5 network , which contains four main components: YOLOv5, Coordinate Attention (CA) attention mechanism module, Bidirectional Feature Pyramid Network (BIfpn), and a Spatial Pyramid Pooling layer (SPP), which are added to the model's 'Neck' . First, the collected video/images are fed to the YOLOv5 network through image processing, then CA is added in the 'Backbone' and the Neck, and the up-sampling in the Neck is replaced with BIfpn, and SPP is also added after the sampled output in each layer. Finally, the detection layer is added to detect abnormal behavior targets using four layers of anchors [9].

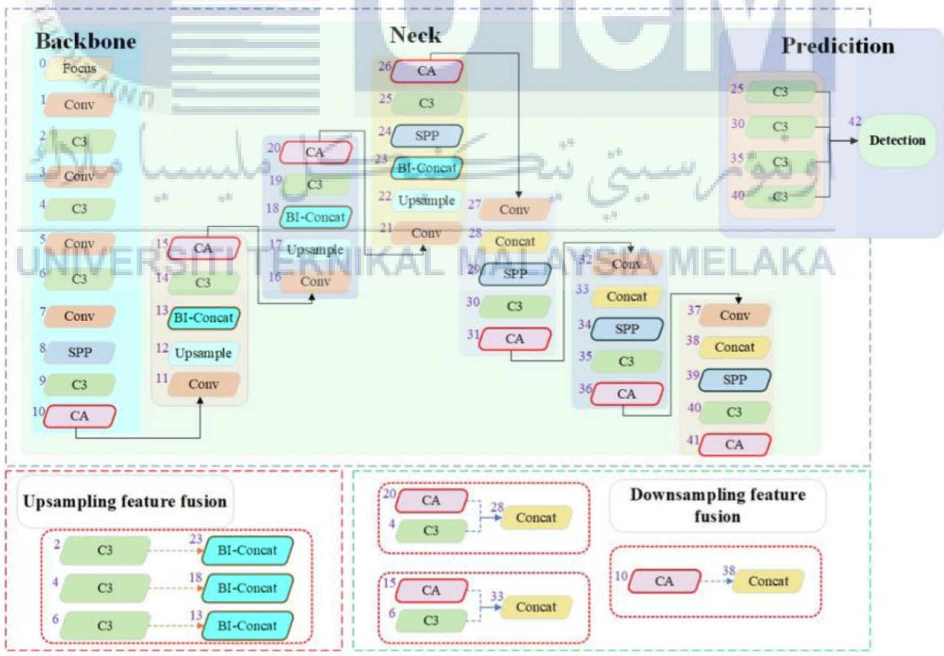


Figure 2.9 An overall schematic of the BCS-YOLOv5-based network structure

2.5 Summary

Therefore , the literature review on fish monitoring systems highlights the importance of these technologies in understanding fish populations and their behavior in aquatic environments. The review covers various components used in fish monitoring systems, including acoustic, optical, and environmental sensors. The study also discusses the advantages and limitations of different monitoring approaches, such as fixed vs. mobile monitoring, and remote vs. on-site monitoring. The literature review emphasizes the fish behavior in different environments such as in normal, low pH levels and hypoxia conditions. Additionally, the review discusses various data analysis techniques used in fish monitoring systems, including algorithms and data acquisition. Overall, the literature review demonstrates the significance of fish monitoring systems in informing fisheries management decisions and conservation efforts.

CHAPTER 3

METHODOLOGY

3.1 Background Method

The methodology chapter of this research presents the approach and techniques employed in the development of a computer vision-based fish monitoring system. This chapter provides an overview of the research flowchart, block diagram, parameters, and testing methods used to capture, process, and analyze underwater images or video streams for extracting valuable information about fish populations, behavior, and habitat preferences. By leveraging computer vision algorithms and machine learning techniques, this research aims to revolutionize fisheries management practices by automating data collection and analysis.

3.2 Research Design

The fish monitoring system project adopted a quantitative research design that involved the systematic collection and analysis of numerical data to answer research questions and test hypotheses. It focused on objective measurement, statistical analysis, and generalizability. In this project, an experimental design type was utilized, which involved manipulating independent variables to observe their effects on dependent variables while controlling for confounding factors.

The project aimed to develop and evaluate the accuracy of the computer vision system in identifying and tracking fish species. A representative sample of fish species and water quality was selected to ensure generalization. The effectiveness of the computer vision system in accurately identifying and tracking fish species was systematically assessed through the manipulation of variables and rigorous statistical analysis.

The experiment consisted of an experimental group that utilized the computer vision system and a specific dataset. Data collection involved capturing images or videos of fish, tagging individual fish for tracking, and recording relevant environmental variables. Statistical analysis, including parameter estimation and hypothesis testing, was conducted to compare the accuracy of fish identification and tracking between the two groups.

The results were interpreted in relation to the research objectives and hypotheses, taking into consideration any limitations identified during the study. Implications for fish monitoring systems were discussed based on the findings, providing insights into the effectiveness of the computer vision system in accurately identifying and tracking fish species.

3.3 Research Flowchart

The research flowchart provides a structured framework for conducting your research on a fish monitoring system using computer vision. It outlines the key phases and steps involved in the project, ensuring a systematic and organized approach to achieve your research objectives. The flowchart serves as a visual representation of the research process, guiding you from the initial literature review to the final evaluation of data and accuracy. Figure 3.1 shows the flowchart of the project research.

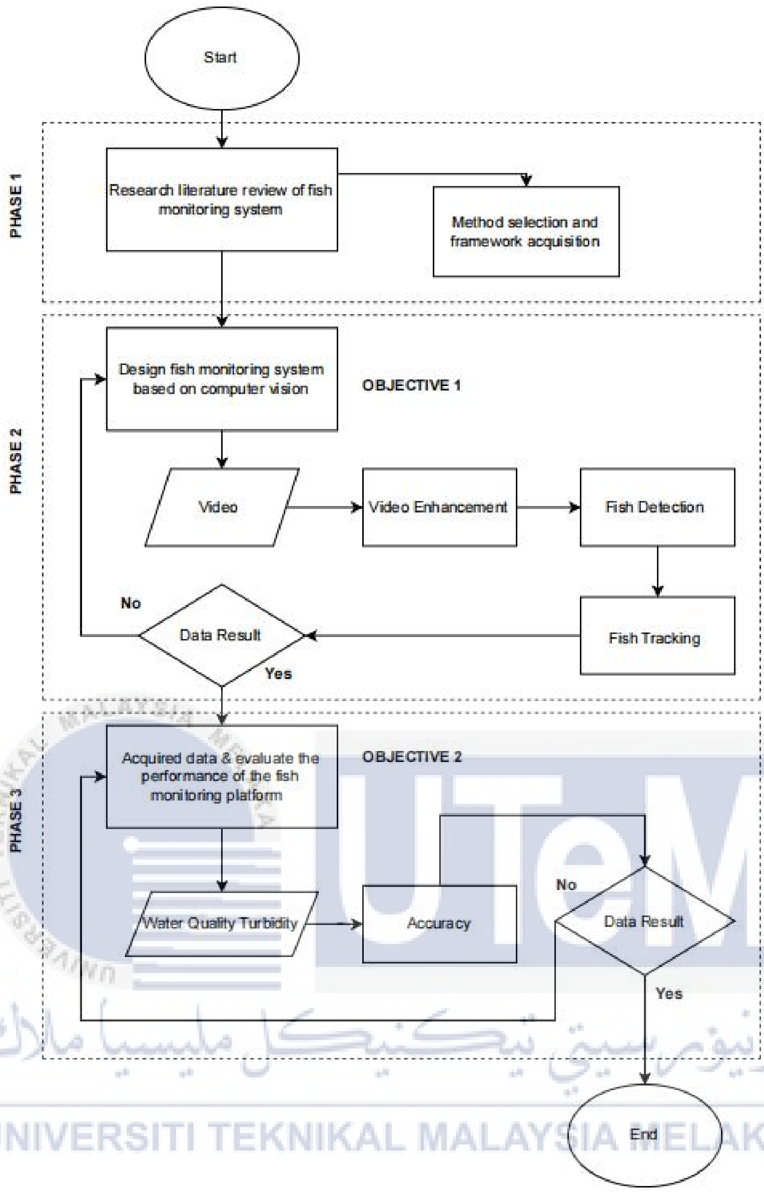


Figure 3.1 Research Flowchart

3.4. Phase Stages

Phase 1 :Research For Literature Review And Method

In this phase, a research will conducted a thorough literature review to gain a comprehensive understanding of existing research, techniques, and technologies related to fish monitoring systems and computer vision. This involves studying scientific papers, journal articles, conference proceedings, and other relevant resources.This phase is crucial for building a solid foundation of knowledge and understanding in the field of fish monitoring systems and computer vision .The key objectives of this phase are to:

a) Understand the existing challenges and gaps in fish monitoring systems.
b) Identify the different computer vision techniques and algorithms used in similar projects.
c) Explore the available datasets and their characteristics for training and testing computer vision models.
d) Investigate the performance metrics and evaluation methods used to assess the accuracy of fish monitoring systems.

Phase 2: Project Development

In this phase, represents the core of the research. This phase involves the practical implementation and development of the fish monitoring system using computer vision.It encompasses various steps, including :

a) Video Capture
b) Image Enhancement phase using Multi-Scale Retinex algorithm (MSR).
c) Object Detection phase using YOLO object detection algorithm.
d) Fish Tracking between different video frames.
e) Data Result.

These steps are designed to guide through the technical aspects of developing a functional fish monitoring system that utilizes computer vision algorithms and techniques.

Phase 3: Data and Accuracy

In this phase, it assess the quality of the acquired data and evaluate the accuracy of your developed system. By evaluating the data quality, you ensure that the collected data is representative and reliable.

3.5 Parameter

In the context of your fish monitoring system project, you can categorize the parameters into fixed and variable parameters. Fixed parameters refer to the characteristics or settings of the system that remain constant throughout the monitoring process. These predetermined parameters include camera specifications, lighting conditions, background environment, and system calibration. They do not change during data collection and analysis. On the other hand, variable parameters are factors that can be manipulated or vary during the monitoring process. These parameters include algorithm settings, data preprocessing techniques, and environmental factors. They can be adjusted to optimize the performance of the computer vision system. By categorizing parameters as fixed or variable, it can identify the aspects that remain constant and those that can be modified, allowing for better control and evaluation of the system's capabilities. This approach facilitates a systematic analysis of the impact of different parameters on the accuracy and effectiveness of the fish monitoring system.

3.6 Selecting and Evaluating Tools

The fish monitoring system using computer vision aligns with several Sustainable Development Goals. Firstly, it contributes to SDG 2: Zero Hunger by promoting sustainable aquaculture practices and ensuring the availability and sustainable management of fish resources. By monitoring fish behavior and environmental conditions, the system optimizes fish condition and promotes healthier fish growth. Secondly, the system relates to SDG 9: Industry, Innovation, and Infrastructure by utilizing advanced technologies such as computer vision and sensors, showcasing innovation in aquaculture and contributing to the development of sustainable infrastructure. Moreover, the system addresses SDG 12: Responsible Consumption and Production by enabling real-time monitoring of water quality parameters, optimizing resource usage, minimizing environmental impact, and improving the efficiency of fish farming operations. Lastly, the system supports SDG 14: Life Below Water by monitoring fish behavior and water quality, helping to conserve and sustainably use marine resources. It detects abnormalities in the fish tank environment, allowing for timely interventions and the maintenance of healthy aquatic ecosystems. Overall, the fish monitoring system contributes to sustainable aquaculture practices, technological innovation, responsible production and consumption, and the conservation of marine life, thus supporting the achievement of multiple SDGs.

3.7 Equipment & Components

3.7.1 Fish Tank

The fish tank serves as the controlled environment where the fish are housed. It provides a contained space for observing and monitoring the fish behavior. The tank's size, shape, and material may vary depending on the fish species and the specific requirements of your project.

3.7.2 Gold Fish

The fish play a crucial role in the data collection process as you observe their behavior, movements, and interactions. Gold fish has been select since the code is already train to detect the goldfish.

3.7.3 DS18B20 Temperature Sensor

DS18B20 is an essential component of the monitoring system. It measures and monitors the temperature of the fish tank water. This data is valuable for assessing the influence of temperature on fish behavior, growth, and overall health. The sensor connected to an Arduino Mega to collect and process temperature readings. The normal temperature for the fishes is around 16 °C - 25 °C.

3.7.4 PH Electrode Probe

The pH sensor measures and monitors the acidity or alkalinity of the fish tank water. Maintaining the proper pH level is crucial for the well-being of the fish. Fluctuations in pH can impact fish health, growth, and behavior. Similar to the temperature sensor, the pH sensor may be integrated with a ArduinoMega for data collection and analysis. The normal pH level for the fishes is around 6.5 until 8.

3.7.5 Turbidity Sensor

Turbidity refers to the cloudiness or haziness of a fluid caused by large numbers of particles that are generally invisible to the naked eye. In the context of aquaculture, turbidity levels in water can be an important indicator of water quality. For the clear water , the NTU is near to 0 in voltage are around 4.1 voltage.

3.7.6 OV7670 Camera

An essential part of the fish monitoring system is the OV7670 camera. It records visual information about the fish and their activities in the tank, such as pictures or videos. All the features of a single VGA camera and image processor chip are provided by the tiny, low-voltage OV7670 Camera Module. The sensor can output the entire frame, sampling, and different resolutions of 8 bits of data via SCCB bus control.

3.7.7 Arduino Mega 2560 R3

An Arduino Mega is a popular open-source microcontroller platform that can be utilized for data collection, control, and integration in your fish monitoring system. It serves as the central processing unit that receives inputs from the sensors, communicates with the camera, and controls various aspects of the monitoring setup. The Arduino can be programmed to collect data from the temperature and pH sensors, trigger the camera for image or video capture, and facilitate communication with a PC for further analysis.

3.7.8 PC

The PC (personal computer) plays a crucial role in data analysis, system control, and visualization. It is used for storing the collected data, running computer vision algorithms to analyze the visual data captured by the camera, and presenting the monitoring results. The PC provides a powerful platform for processing and interpreting the data collected from the sensors and camera.

3.8 Block Diagram

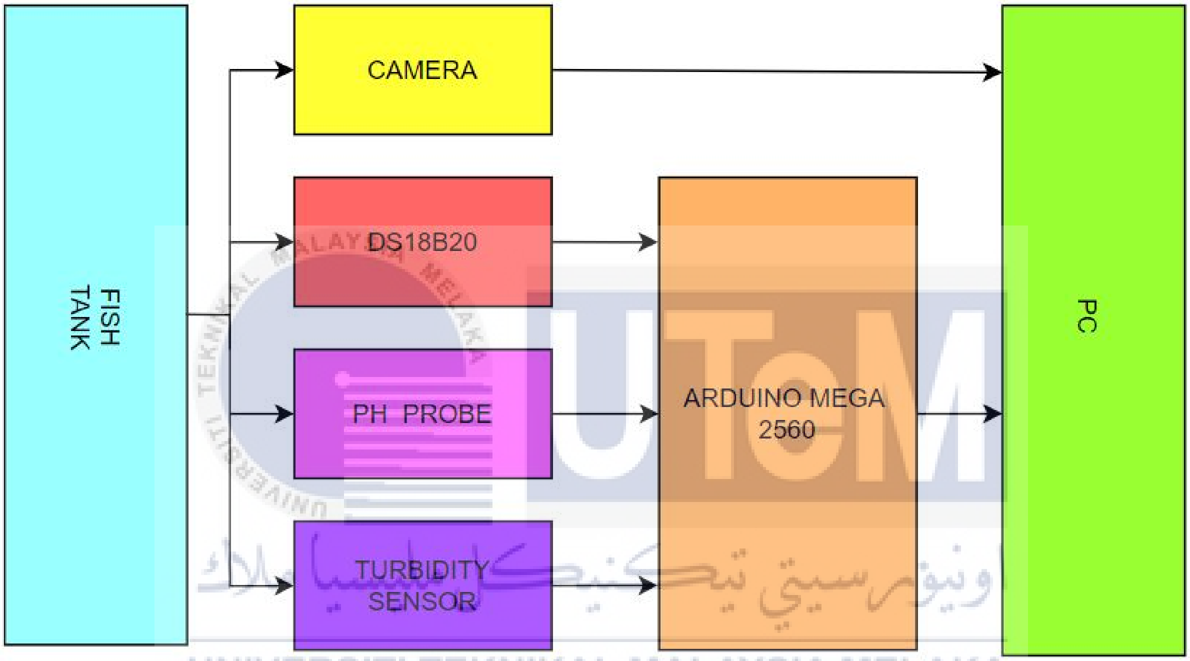


Figure 3.2 Fish Monitoring System Block Diagram

The project's block diagram is displayed in Figure 3.2. This project has four inputs: a camera, a pH sensor, turbidity sensor, and a temperature sensor, with a computer serving as the output. The fish footage is captured in real time by the camera and sent to the PC for processing starting from the fish tank where the fish are housed. On the other side, the pH level, water clarity and water temperature are detected by the sensors. Since the sensor cannot be connected to a computer directly, both data are sent to Arduino Mega. Arduino Mega is used instead Arduino UNO since the sensor and camera need more analog pin for connection. Data from the Arduino will be sent to the PC. The PC will use an algorithm to process the data received from the input and display the results.

3.8 Connection

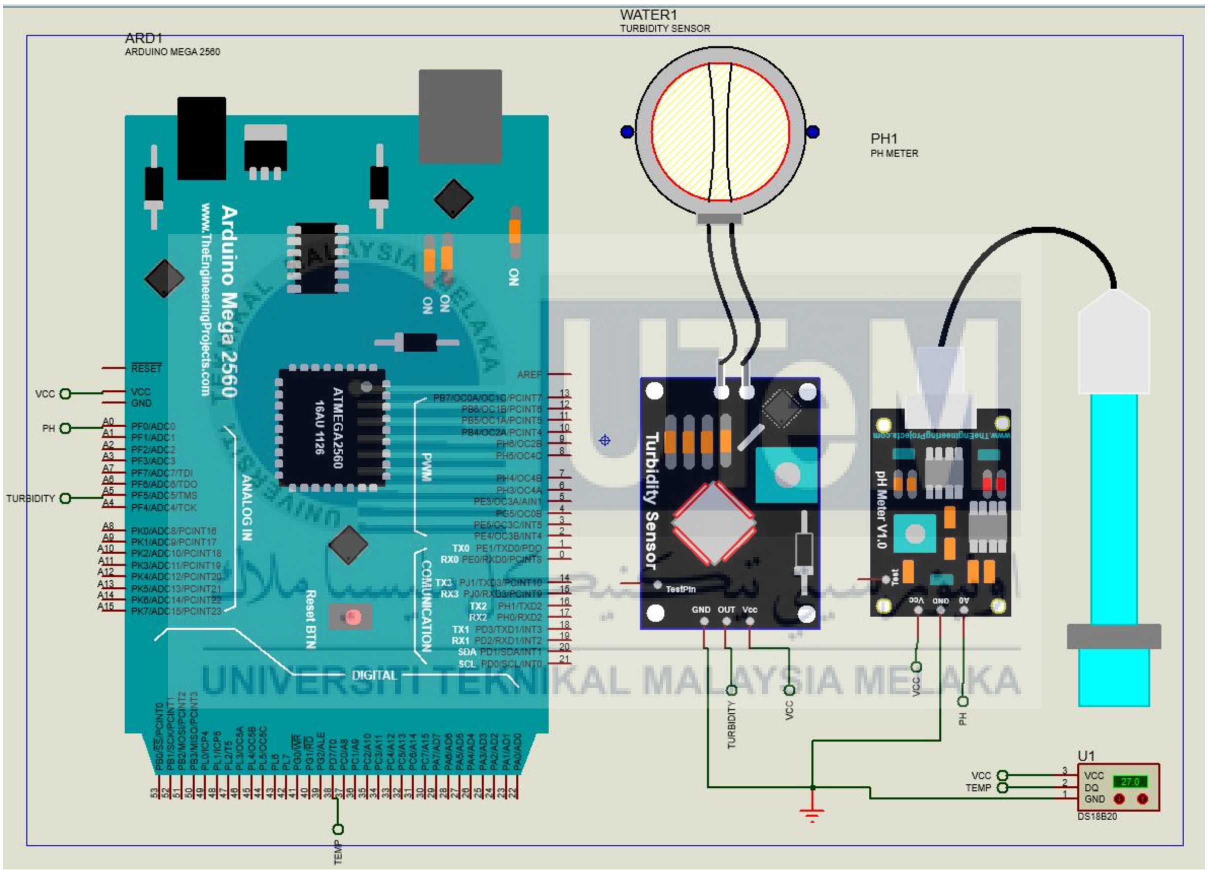


Figure 3.3 Sensors Connection To Arduino Mega 2560

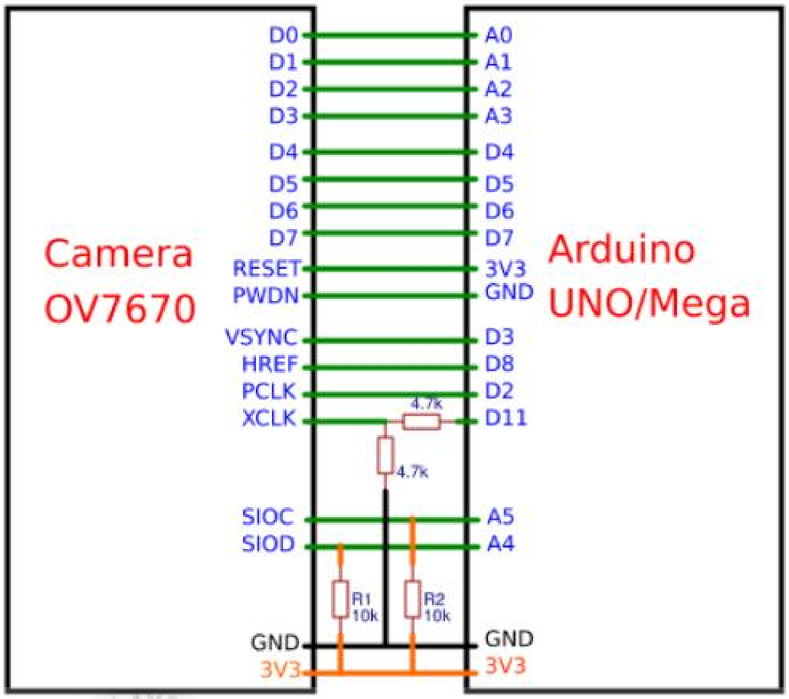


Figure 3.4 OV7670 Connection To Arduino Mega 2560

The connection for the hardware circuit are been connected based from the Figure 3.2 and Figure 3.4. Figure 3.3 shows the connection for the sensors DS18B20,PH Sensors and Turbidity sensors to Arduino Mega 2650. The PH sensor and turbidity sensor data output were in analog signal so both sensor data need to connected to analog pin which in this case it connected to pin A0 and pin A5. For DS18B20 Temperature sensor the data output was in digital so it can directly connected to digital pin 30. As for the OV7670, the connection was shows in Figure 3.4 . It required 2 4.7kΩ and 10kΩ resistor to protect the camera form burnout.

3.9 Phyton Code

```python
import cv2
import numpy as np
from numpy.linalg import norm
import math
import csv
from operator import itemgetter
from datetime import datetime
import VideoEnhancement
import fishpredictor
import detector
import kmeancluster
import preproccesing
import randomforst
import os

# Initialize objects
cluster = kmeancluster.kmeans()
classifier = randomforst.randomforst()
samak = []
```

Figure 3.5 Main Code

```python
import numpy as np
import cv2


def singleScaleRetinex(img, sigma):

    retinex = np.log10(img) - np.log10(cv2.GaussianBlur(img, (0, 0), sigma))

    return retinex

def multiScaleRetinex(img, sigma_list):

    retinex = np.zeros_like(img)
    for sigma in sigma_list:
```

Figure 3.6 Video Enhancement Code


```python
import cv2
import numpy as np
class detector:
    def __init__(self):
        self.net = cv2.dnn.readNet("yolov3-tiny-obj_9000327.weights", "yolov3-tiny-obj326.cfg")
        self.classes = []
        with open("obj.names.txt", "r") as f:
            self.classes = [line.strip() for line in f.readlines()]

        layer_names = self.net.getLayerNames()
        self.output_layers = [layer_names[i - 1] for i in self.net.getUnconnectedOutLayers()]
        self.colors = np.random.uniform(0, 255, size=(len(self.classes), 3))

    def detect(self,img):
        height, width, channels = img.shape
        # Detecting objects
        blob = cv2.dnn.blobFromImage(img, 0.003, (416, 416), (0, 0, 0), True, crop=False)
```

Figure 3.7 Fish Detection Code

The above figure depicts a portion of the phyton that was used in this project.The main code functions as the primary code and imports all other codes. First step after receive the image frame, it will proceed by the Multi-Scale Retinex (MSR) algorithm, the image is passed to the Single-Scale Retinex which subtract the logarithm of the image from the logarithm of the same image but applied Gaussian filter to it. Subsequently, the picture is submitted to the Multi-Scale Retinex, yielding outcomes that are more precise and efficient.

Then, using YOLOv3, which has a reasonable real-time accuracy, fish were identified. The algorithm determines the classes and region of interest for the image in a single algorithm run because it is a regression-based object detection algorithm. The code that was trained by the previous user using the dataset with the YOLO tiny weights was dropped after 9000 epochs because the average loss rate did not show any improvement over the previous 2000 iterations.Since the tiny weights file is a lighter version of the yolov3 weights and is intended for models with fewer classes, it was used for training rather than the yolov3 weights.

To enable tracking of the fish throughout the video frames, each fish that is discovered is given a unique label, or ID. Fish between frames must be tracked because if fish detection by YOLO does not track fish frame by frame, fish may be incorrectly classified. Fish tracking requires that the x and y positions of each object for the eight previous frames of the video be stored in an array, as well as the saving of each object's centre point in a frame.

3.10 Arduino Code

```
Sensor_Comb

#include <OneWire.h>
#include <DallasTemperature.h>
#define SensorPin A0          // the pH meter Analog output is connected with the Arduino's Analog

unsigned long int avgValue;  //Store the average value of the sensor feedback
float b;
int buf[10],temp;
float calibration_value = 32;
const int SENSOR_PIN = 30; // Arduino pin connected to DS18B20 sensor's DQ pin

OneWire oneWire(SENSOR_PIN);         // setup a oneWire instance
DallasTemperature tempSensor(&oneWire); // pass oneWire to DallasTemperature library

float tempCelsius;    // temperature in Celsius
float tempFahrenheit; // temperature in Fahrenheit

void setup()
{
  Serial.begin(9600); // initialize serial
  tempSensor.begin();    // initialize the sensor
  pinMode(13,OUTPUT);
  Serial.begin(9600);
  Serial.println("Ready");    //Test the serial monitor
}

void loop()
{
  tempSensor.requestTemperatures();             // send the command to get temperatures
  tempCelsius = tempSensor.getTempCByIndex(0);  // read temperature in Celsius

  Serial.print("Temperature: ");
  Serial.print(tempCelsius);    // print the temperature in Celsius
  Serial.println("°C");
  delay(500);
```

Figure 3.8 Arduino Code

Figure 3.8 shows a part of arduino code that used to execute te sensors functionality. Since DS18B20 was in digital so it was directly read , but for the turbidity and ph sensor both of it in analog output so it need to convert the obtained output into voltage value . For DS18B20 was connected to digital pin 30, Turbidty sensor connected to analog pin A5 and ph sensor connected to pin A0.

3.11 Summary

In order to summarize this chapter, this project is based on quantitative research design and emphasizes experimental type because the major goal of the project is to monitor fish. The research flowchart depicts the progression of the project's three phases, including research, development, and data collection. The fixed and variable parameters have been determined. Other than that, the flowchart and block diagram effectively show the hardware and software flow. It begins with the capturing of a video, which is then processed in a computer using a predetermined algorithm before the data is shown.

CHAPTER 4

RESULT & DISCUSSION

4.1 Introduction

This project's chapter described the setup and results of a fish monitoring system based on computer vision. The setup, sensor output, computer vision output, data analysis, and discussion will all be covered in this chapter. To provide a thorough analysis, the conversation will go into further detail regarding the outcome and the output that was observed.

4.1 Setup

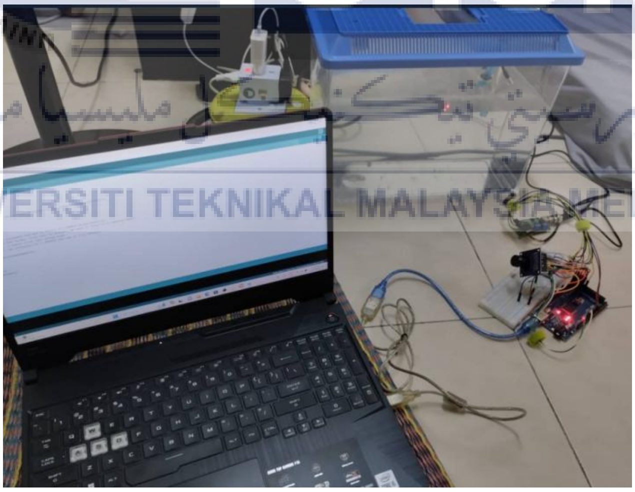


Figure 4.1 Overall Setup

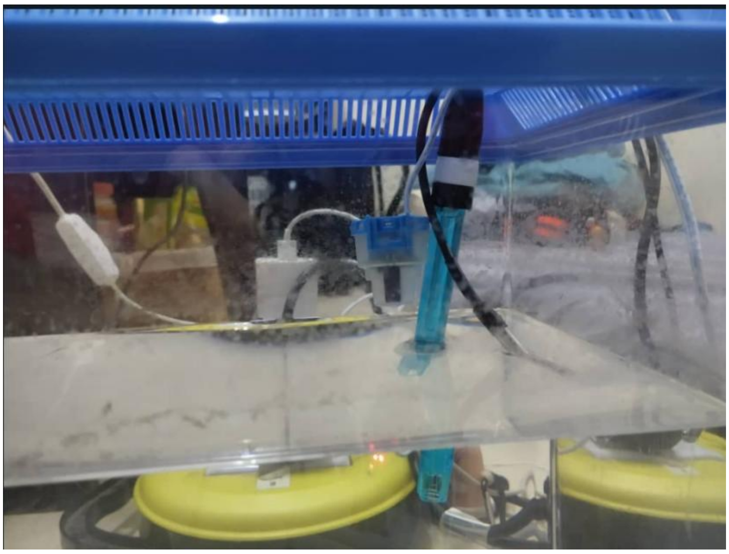


Figure 4.2 Sensors Setup

Figure 4.3 4 Golfish In Tank

All of the hardware had been configured using the connection methodology as indicated in Figure 4.1. To keep it from falling into the water, the sensors were submerged in water and affixed to the hole punched in the cover. Two small and two large goldfish were used in this project as displayed in Figure 4.3.

4.2 Algorithm Output

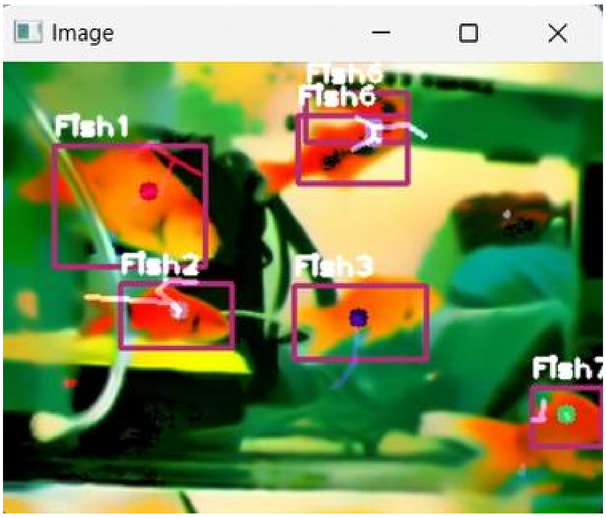


Figure 4.3 Alghorithm Detect The Fishes

Figure 4.4 Alghorithm Tracking The Fishes

The algorithm was demonstrated in Figures 4.3 and 4.4 to detect and track the fish.. Fish movement was seen in Figure 4.4 a few seconds after Figure 4.3. At first , the video were enhance by the Multi-Scale Retinex (MSR) algorithm. After that it , the YOLOv3 alghorithm will detect the goldfish and tracking it by assign the ID .

4.3 Sensor Output

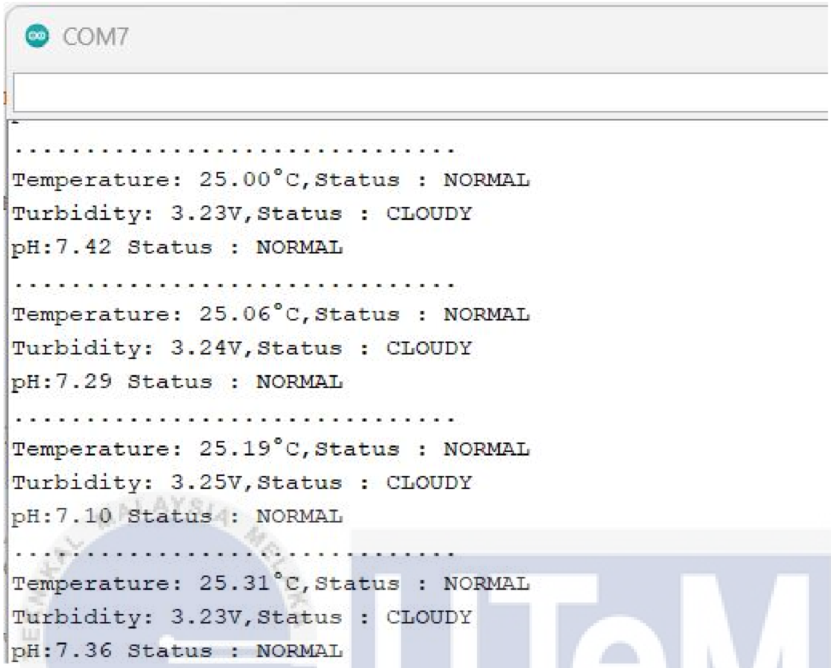


Figure 4.5 Sensors Value Displayed In Serial Monitor

After the code was uploaded to the Arduino Mega, the serial monitor of the sensor value was displayed in Figure 4.5. The displayed value is state where the sensors is dip in a clear water and room temperature .There were 3 result shown in serial monitor which were temperature , turbidity and ph. The room temperature was around 23°C - 28°C and normal ph level for water is 7, turbidity above 4.1V is a clear water.

4.4 Discussion

By undergo the process of doing this research; few challenges were faced to be overcome . First problem also is the main problem that occurs is because of the camera. The OV7670 is one of the cheapest camera in the market however it hard to capture moving objects and the frame will blur the image capture since it only offer resolution of 640x480 for 30 fps with 0.3 Megapixel so the output obtained is not clear whenever the fish start moving. Other than that, The camera wired can't be jumping to long because of the low voltage of the camera so the data unable to transfer in long distance due to data loss. This problem lead to the immobility of the camera make it hard to set the camera and clash with other wired since the camera need to keep close with Arduino. The number of pin need to connected with Arduino also another problem with this camera. With the 17 pin need to connect , it hard to connect with Arduino with the pin is connected close with each other plus with the short jumpers.

Furthermore , others flaws that can be observed from this project is the fish selection. Goldfish can be relatively easy to keep as pets, but they do require proper care and attention. They need a suitable environment with a well-maintained tank, proper filtration, and regular water changes. Additionally, they require a balanced diet and proper feeding. Failed doing this can lead to decease of the fishes.

Apart from that, one of the reasons the accuracy data could not be obtained was the turbidity sensor malfunctioning. The sensor's output remains unchanged, not even altering the medium. Given that the code is correct, the issue is most likely with the sensor or the module itself.

Lastly , the others minor problem with the projects is the length of the sensors where it need to be short due to error value, Unorganized wired and proper setup, and the project are limited in performance due to tight budget.

4.5 Data analysis

To draw meaningful conclusions, a comprehensive data analysis is conducted by examining the interplay of the water quality and the lighting effect. The data analysis is conducted to evaluate the accuracy of the system.

4.5.1 Water quality

Figure 4.6 Clear Water

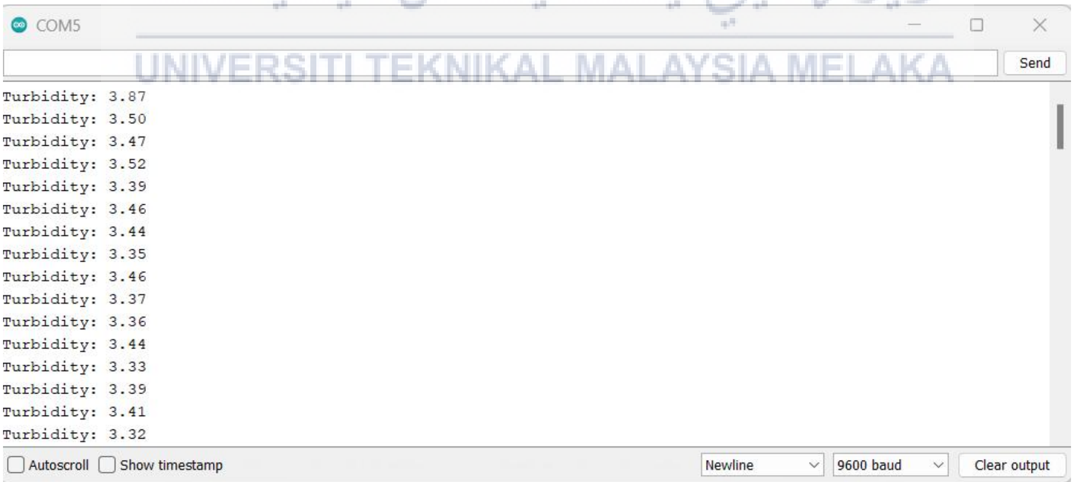


Figure 4.7 Clear Water Output

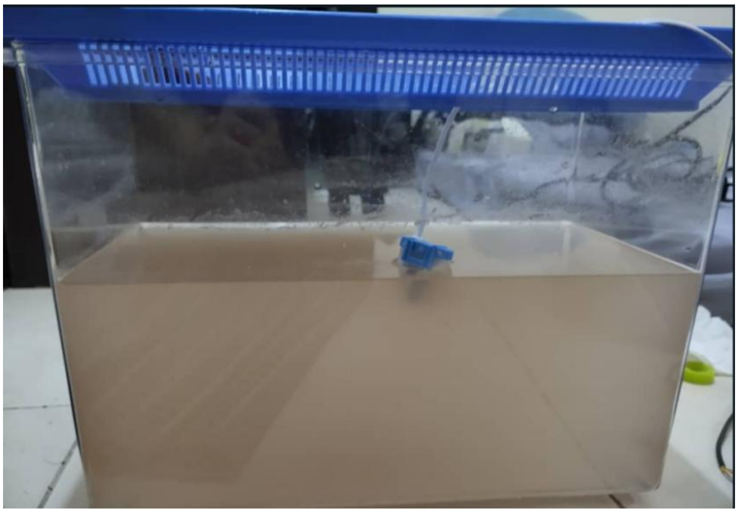
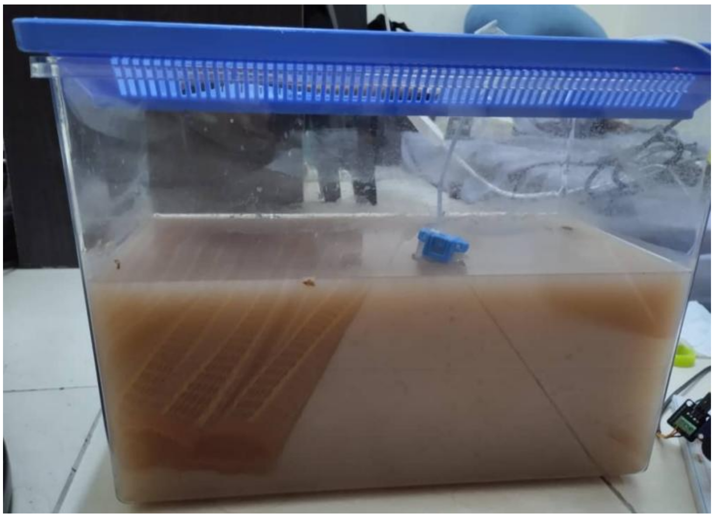


Figure 4.8 Slightly Dirty Output

Figure 4.9 Slightly Dirty Output



4.10 Dirty Output

Figure 4.11 Dirty Output

For this experiment, the turbidity of the water is been tested. This test is to see the accuracy of the turbidity sensor to generate voltage value . The sensor been tested in 3 state , clear water , slightly dirty and dirty. The water is mix with coco powder to imitate the dirt . In clear water state , the average of the turbidity is 3.432 V. In slightly dirty state the average of the turbidity is 4.111V. In dirty state , the average of the turbidity is 4.173V. For clear water the NTU of the water supposedly below 1 NTU or in voltage around 4.1±0.3V. So 3.432 / 4.1 x 100% = 83.71% of the accuracy for clear water. For the coco mixture is hard to compare with the real NTU since that the concentration of the coco is not measurable. But, according to theory, the more turbidity water is the less the voltage value.

CHAPTER 5

CONCLUSION & FUTURE RECOMMENDED

5.1 Conclusion

In conclusion, an operational computer vision-based fish monitoring system for aquaculture has been developed. The primary goals of this project are to develop a computer vision platform-based fish monitoring system and assess the accuracy of the platform's performance using statistical methods.

The developed fish monitoring system utilizing computer vision technology presents a comprehensive solution for monitoring fish environment and detect the fish in aquatic environments. The system's ability to detect fish in real-time and monitor water quality so it can provides valuable insights for scientific research, fisheries management, and aquaculture industries. However the project is still in prototype due to certain factor such as equipment type to generate a desired output .

5.2 Future Recommendation

There is a lot that can be improved in this projects , but the major factor that need to take consider is the camera type . It is suggested to replace with digital camera so it can obtain a better frame resolution and better fish tracking. Other than that , this projects need other water control equipment such as water filter , oxygen pump and better food to prolong the goldfish lifespan. Lastly , this projects can be enhance by adding the user interface such as Blynk app. For example , add notifications whenever Ph level is high or low , the water is to cloudy or the temperature is abnormal to users.

REFERENCE

[1] K. N. Hairol, R. Adnan, A. M. Samad, and F. Ahmat Ruslan, “Aquaculture Monitoring System using Arduino Mega for Automated Fish Pond System Application,” *2018 IEEE Conference on Systems, Process and Control (ICSPC)*, 2018. doi:10.1109/spc.2018.8704133

[2] G. Xiao, W. Zhang, and Y.-L. Zhang, “Online monitoring system of fish behavior,” *2011 11th International Conference on Control, Authomation and System*, Oct. 2011.

[3] F. Yuan, Y. Huang, X. Chen, and E. Cheng, “A biological sensor system using computer vision for water quality monitoring,” *IEEE Access*, vol. 6, pp. 61535–61546, 2018. doi:10.1109/access.2018.2876336

[4] F. Budiman, M. Rivai, and M. A. Nugroho, “Monitoring and control system for ammonia and ph levels for fish cultivation implemented on Raspberry Pi 3B,” *2019 International Seminar on Intelligent Technology and Its Applications (ISITIA)*, 2019. doi:10.1109/isitia.2019.8937217

[5] Y. W. Mohamad Yusof, M. Kassim, and N. A. Noor Azlan, “Design and analysis of IOT-based aquarium monitoring system for guppy fish habitats,” *2022 12th International Conference on System Engineering and Technology (ICSET)*, 2022. doi:10.1109/icset57543.2022.10010912

[6] T. E. Suherman, M. H. Widianto, and Z. Athalia, “Internet of things system for freshwater fish aquarium monitoring and automation using Iterative Waterfall,” *2022 4th International Conference on Cybernetics and Intelligent System (ICORIS)*, 2022. doi:10.1109/icoris56080.2022.10031310

[7] M. M. Billah, Z. M. Yusof, K. Kadir, A. M. Ali, and I. Ahmad, “Quality Maintenance of Fish Farm: Development of real-time water quality monitoring system,” *2019 IEEE International Conference on Smart Instrumentation, Measurement and Application (ICSIMA)*, 2019. doi:10.1109/icsima47653.2019.9057294

[8] E. Lantsova, T. Voitiuk, T. Zudilova, and A. Kaarna, “Using low-quality video sequences for fish detection and tracking,” *2016 SAI Computing Conference (SAI)*, 2016. doi:10.1109/sai.2016.7556017

[9] X. Li, Y. Hao, P. zhang, M. Akhter, and D. Li, “A novel automatic detection method for abnormal behavior of single fish using image fusion,” *Computers and Electronics in Agriculture*, vol. 203, p. 107435, 2022. doi:10.1016/j.compag.2022.107435

[10] D. Li *et al.*, “Automatic recognition methods of fish feeding behavior in aquaculture: A Review,” *Aquaculture*, vol. 528, p. 735508, 2020. doi:10.1016/j.aquaculture.2020.735508

[11] C. Lee and Y.-J. Wang, “Development of a cloud-based IOT monitoring system for fish metabolism and activity in Aquaponics,” *Aquacultural Engineering*, vol. 90, p. 102067, 2020. doi:10.1016/j.aquaeng.2020.102067

[12] H. Wang *et al.*, “Real-time detection and tracking of fish abnormal behavior based on improved yolov5 and SIAMRPN++,” *Computers and Electronics in Agriculture*, vol. 192, p. 106512, 2022. doi:10.1016/j.compag.2021.106512

[13] D. Li, G. Wang, L. Du, Y. Zheng, and Z. Wang, “Recent advances in intelligent recognition methods for fish stress behavior,” *Aquacultural Engineering*, vol. 96, p. 102222, 2022. doi:10.1016/j.aquaeng.2021.102222

[14] Y. Mei *et al.*, “Recent advances of target tracking applications in aquaculture with emphasis on fish,” *Computers and Electronics in Agriculture*, vol. 201, p. 107335, 2022. doi:10.1016/j.compag.2022.107335

[15] L. Sun *et al.*, “Water quality parameter analysis model based on fish behavior,” *Computers and Electronics in Agriculture*, vol. 203, p. 107500, 2022. doi:10.1016/j.compag.2022.107500

[17] X. Zeng, “Bio-inspired simulation with learning-based automatic motion control,” thesis

[16] J. Qian, Y. Dong, and X. Xiao, “Solar powered wireless water quality monitoring system for ornamental fish,” *Results in Engineering*, vol. 17, p. 101016, 2023. doi:10.1016/j.rineng.2023.101016

[18] S. Banerjee, “A study on biologically-inspired recognition using multi-platform and multi-modal data,” thesis

[19] J. Engdahl, “Developing An Automated Analysis Of Fish Migration Video using Computer Vision Alghorithm,” thesis, 2020

[20] S. S, M. P. M, U. Verma, and R. M. Pai, “Computer Vision based fish tracking and behaviour detection system,” *2020 IEEE International Conference on Distributed Computing, VLSI, Electrical Circuits and Robotics (DISCOVER)*, 2020. doi:10.1109/discover50404.2020.9278101

[21] Q. Wang, W. Long, Y. Wang, L. Jiang, and L. Hu, “Fish behavior detection using computer vision: A Review,” *2021 3rd International Conference on Artificial Intelligence and Advanced Manufacture (AIAM)*, 2021. doi:10.1109/aiam54119.2021.00082

[22] X. Li, M. Liu, S. Zhang, and R. Zheng, “Fish trajectory extraction based on object detection,” *2020 39th Chinese Control Conference (CCC)*, 2020. doi:10.23919/ccc50068.2020.9188642

[23] O. Anas *et al.*, “Detecting abnormal fish behavior using motion trajectories in ubiquitous environments,” *Procedia Computer Science*, vol. 175, pp. 141–148, 2020. doi:10.1016/j.procs.2020.07.023

[24] J. Hu, D. Zhao, Y. Zhang, C. Zhou, and W. Chen, “Real-time nondestructive fish behavior detecting in mixed polyculture system using deep-learning and low-cost devices,” *Expert Systems with Applications*, vol. 178, p. 115051, 2021. doi:10.1016/j.eswa.2021.115051

[25] S. S, M. P. M, U. Verma, R. M. Pai, and G. S, “Behavioural pattern analysis of fishes for smart aquaculture: An object centric approach,” *TENCON 2021 - 2021 IEEE Region 10 Conference (TENCON)*, 2021. doi:10.1109/tencon54134.2021.9707293

[26] R. Md. Hashibur, H. Mohammad Mahfujul, A. Mohammad Ashraful, and F. Flura, “A study on the specific growth rate (SGR) at different stages of tilapia (Oreochromis niloticus) production cycle in tank based aquaculture system,” *International Journal of Aquaculture and Fishery Sciences*, vol. 8, no. 2, pp. 059–065, 2022. doi:10.17352/2455-8400.000079

[27] X. Mouy *et al.*, “FishCam: A low-cost open source autonomous camera for Aquatic Research,” *HardwareX*, vol. 8, 2020. doi:10.1016/j.ohx.2020.e00110

APPENDICE

Appendix A Turnitin Report

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ORIGINALITY REPORT

23%	8%	19%	3%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Xin Li, Yinfeng Hao, Pan zhang, Muhammad Akhter, Daoliang Li. "A novel automatic detection method for abnormal behavior of single fish using image fusion", Computers and Electronics in Agriculture, 2022 Publication	9%
2	www.researchgate.net Internet Source	3%