# Underwater Environmental Robotic Fish

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***Abstract*—Robotic Fish and Artificial intelligence is becoming one of the most prominent research discoveries of our Time. The advance technology, software engineering, big data and extensive trials has led to its success. Many robotic fish research are being found all over the web. Each helps cater to our environmental, cyber warfare, and machine learning needs. However, Robotic Fish are not to be linked to underwater drones, but are linked to reducing of global warming, greenhouse gases, and the extinction of other underwater life. Robotic Fish and Artificial intelligence provide a special outlook on intellectual implementation results for educational resources.**

***Index Terms*—Robotic Fish, Artificial Intelligence, Big data, Machine Learning, Amazon, Underwater Environmental Clean up, Cleaner Fish**

## I. Introduction

The most important thing to do in order to address climate change is try to better understand the environment we are in and how different environmental factors contribute to climate change. When placed in a body of water, Robotic fish can gather and provide us with different kinds of information from its surroundings. For example, a swarm of fish can be dispatched into a large body of water to monitor different fish behavior, water quality, and underwater phenomena. Scientists can then collect and analyze this data to help us better understand that area. There are currently a wide variety of robots being used in the oceans. Robots with artificial intelligence are very important and they provide us with a wide range of advantages - they help reduce the loss of human life in risky environments, and provide quality assurance, efficiency, and consistency. Liquid robotics, a startup in San Francisco has created wave-riding robots which can be used to track fish, Predict tsunami's and discover oil leaks around drilling platforms. A prototype of robot fish has been created to detect pollution, find out pH of water and report to a computer. [1] Robots are also used for large scale water quality monitoring, environment monitoring and event detection [2]. Richard Hardiman of RanMarine is using small robots in Rotterdam called waste sharks that catches garbage before it works it's way into the sea [3]. Robots are also used to facilitate deeper understanding of marine life with minimally disruptive observations. SoFi, an untethered soft-bodied robotic fish that demonstrates prolonged and consistent underwater remote-controlled operations was built by MIT researchers [4]. Our research is to design, develop and control a robotic fish using artificial intelligence and analyzing it's behavior when it is subjected to a test in an artificial water body.

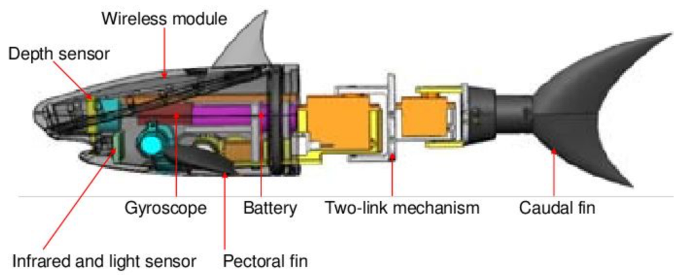


Figure 1: Conceptual design

Figure 2: Robotic prototype

## II. Literature Review

### A. Current Design and Model Configurations for AI Enabled Robot Fish

*1) Experimental Modeling and Motion Control for Underwater Robotic Fish [5]:* The majority of concern when it comes to designing a 3D robotic fish is its technology. Special algorithms and programming languages like Python help with the movement and the simplified robotics of the design [5]. The robotic fish's movement will be monitored through a remote camera on the fish's fin. The findings will be analyzed on the computer to enable the results and see how it functions using its body to propel and motion itself in the water. The data collected will be based on the 3D robotic fish's interaction with other fishes as well, including its ability to camouflage itself when danger is near. This would depict if the robotic fish has what it takes to live amongst the other fishes in their "natural" habitat. Artificial intelligence is one of the most complex subjects and has many difficulties when being applied to robotics. The artificial intelligence will be encrypted on a chip and inserted within the head of the robotic fish. Therefore, when applying artificial intelligence to the 3D robotic fish, there needs to be careful caution with its necessity. It is easy to replace the robotic fish, but developing the artificial intelligence is not so easy. The Robotic fish's artificial intelligence will provide its nature of posing as a fish. The robotic fish would become one with nature. The mechanical system and its now "fish instinct" will help it to adapt and evolve like other fishes. The 3D robotic fish would have the potential to dive about 3 meters under water to enable its fish like movement [6]. Any time of motion patterns will then be included in the data research. There would also be a GPS on the tail of the robotic fish to ping each location the fish swim to. Also by creating a formula and using the GPS the number of meters the robotic fish swam will also be used as significant data [7]. Furthermore, these results will be used as an education guide for University based research and experiment.

*2) Analysis of Robotic Fish Using Swarming Rules with Limited Sensory Input [8]:* Sensory features are going to be a main benefit to building a robotic fish. Fish are known to depend on their skill to sense the environment around them and to swarm together with other fish to strengthen their chance of survival in wild sea life. For robotics, researchers have tried to copy fish's ability and learn the environment around them to make the robotic fish as realistic (behavior wise) as possible. The effects of their different sensory capabilities have been paired with a few basic swarming "rules" to figure out what the robotic fish will need to not only interact with by act like real fish. The goal of this research is to create an organic-like fish that will eventually evolve to monitor and study a school of fish. Although it would have been beneficial to have and test a physical model/prototype, because of time and cost constraints, a virtual environment and model was done to further the experiment. Having the robotic fish created and tested in a virtual simulation permits limitations like; which sensory skill will be used at any given time and how quickly it can adjust to switching between the skills necessary for the situation or environment the robotic fish I placed in. Creating the testing subject and environment virtually has also presented the advantage of being able to make modifications to both the design of the fish and the interacting or sensory features much simpler. By testing the different sensory types that organic fish have on the robotic fish, it shows how effective the robot fish will be in blending in with real swarms of fish and how they respond to a controlled and continually changing environment.

*3) Insight of a Six Layered Neural Network along with other AI Techniques for Path Planning Strategy of a Robot [9]:* It is key to find a suitable artificial intelligence algorithm to steer our robotic fish in familiar/unfamiliar territories. Several prior researches show us that different techniques can be used for robot maneuvering. Layered artificial neural networks can be used so that the input layer captures the distance between the fish and its surroundings and the output layer gives the fish a steering angle in which it should move. [9] Central pattern generators are also used to control postures of robot fish. CPG is a biological neural network that can generate motion pattern used to control fish postures [10]. Achieving fish-like capabilities in maneuverability and efficiency in an automotive vehicle will require the tight integration of both design and control development. [11]

*4) Model Predictive Control for Underwater Robots in Ocean Waves [12]:* Based on the research paper "Model Predictive Control for Underwater Robots in Ocean Waves" [12], wave displacement and water disturbances can be effectively resisted and even counteracted with the implementation of the model predictive control method (MPC). The component fluid dynamics underneath ocean wave fields can be forecasted/estimated using linear wave theory (LWT) which is employed by MPC. The method suggested in this article is thought to increase the confidence in robotic observations in shallow ocean water and can even reduce damage done to robotic fish stations by water disturbances. MPC utilizes a sequence of input controls to minimize global cost function (deviation/squared distance from the target state). An optimized projected trajectory is modeled and then executed using thrusters which counteract the negative effects of the majority of water disturbances.

## III. Project Requirements

### A. The project requirements needed are as follows:

*1) A control unit with microprocessors and peripherals:* A "control unit" with microchips,"microprocessors, remote, peripherals, mini suction vacuum and a computer [5]. This would give us total control over the robotic fish's movement and how much garbage it needs to pick up in a maximum set of time.The control unit will also have a sector for the "communication unit", which includes wireless mic, sensors, and algorithms. The wireless mic will tell the fish to wake up and to begin collecting garbage. The sensors would indicate the surrounding area of the robotic fish position. The algorithm is significant in the speed and control of the Robotic's fish cleaning capabilities. The robotic fish's " support unit" is from its soft exoskeleton body (head and body) which is made of silicon [5]. There is also an "activation unit" that requires batteries, wiring, GPS, mini camera, gas tube chamber (breathing mechanism), five rotating motors and the robotic fish's tail and fin [13].

*2) Robotic Fish Movement:* In order for the robotic fish body to move from location to location to vacuum up the underwater waste,we would need a formula for the entire body movement. A little more than half of the body is being moved at an altitude so that the robotic fish can swim at both surface level and deeper into the water to collect any unknown objects in the water with its suction vacuum. Approximately  of the body including the tail does most of the movements and the rest of motions for turning is based on the fins and the head in the The expectancy for the altitude is equal to or less than zero. A Robotic fish's motion can be divided into two separate parts. One part is the flexible silicone body and the second part is its two oscillating fins, and six joints, which is used for the robotic fish's high performance and self containment [5]:

$$ybody(x,t) = [(c1x + c2x2)][Sin(kx + wt)])$$

The formula above indicates direction of the robotic fish's movement. The interval ybody is equal to the diagonal displacement of the robotic fish as it is moving side to side or going across the water to suck up the garbage with its mouth.The x variable represents the displacement as the robotic fish moves vertically in the water. The k variable shows the body wave amount (k=2/lambda). Lambda indicates the robotic fish's wavelength [6].

### B. Speed Control Algorithm and Robotic Kinetics:

As the robotic fish swims in the water, its body speeds up by rotating the pattern of the motors in the tail and the fins, which produced oscillating frequency. The suction vacuum is also produced by the Robotic fish's motors as well. The momentum is built up as the fish interacts with the waters and changes its frequencies. The fish should be able to accelerate and also decelerate when cleaning the area underwater going from its initial velocity (Vi ) to its final velocity (Vf). However, with the inertial force and hydrodynamic force, the robotic fish should be able to control its speed and slow down to make any sudden turns or stop if it senses danger or sees more garbage to clean up.

The potential energy in the robotic fishes movement needs to be manipulated in order to promote change. The maximum acceleration is represented by the symbols Am , this can be restricted by the inertia force. Therefore the robotic fish should swim only from its initial velocity (Vi) to its final velocity (Vf). While it decreases in velocity, so does its frequency (f). Then the robotic fish's speed would become zero and it will drifts as the water current moves its body. Since the speed becomes zero then that implicated the hydrodynamic control is achieved [6].

Table I: Technical Specifications for a Prototype Robot Fish

| Specification Type | Specification Value |
|---|---|
| Size (L x W x H) | 13" x 3" x 5" |
| Weight | 1kg |
| Number of joints | 6 |
| Oscillating Frequency | 4 Hz |
| Length of oscillating tail & fins | 7 inches |
| Max speed | 1 m/s |
| Minimum turning speed | 0.45 m/s |
| Max torque | 44.1 psi (pascals) |
| Drive Mode | Tail & fin motors |
| Control Mode | Remote |

*1) Speed Control Algorithm and Robotic Kinetics:* As the robotic fish swims in the water, its body speeds up by rotating the pattern of the motors in the tail and the fins, which produced oscillating frequency. The momentum is built up as the fish interacts with the waters and changes its frequencies. The fish should be able to accelerate and also decelerate when needed for its initial velocity (Vi )and its final velocity (Vf). However, with the inertial force and hydrodynamic force, the robotic fish should be able to control its speed and slow down to make any sudden turns or stop if it senses danger. The potential energy in the robotic fishes movement needs to be manipulated in order to promote change. The maximum acceleration is represented by the symbols Am , this can be restricted by the inertia force. Therefore the robotic fish should swim only from its initial velocity to its final velocity. Vi Vf .While it decreases in velocity, so does its frequency (f). Then the robotic fish's speed would become zero and it drifts as the water moves its body. Since the speed becomes zero then that implicated the hydrodynamic control is achieved. [5] [14]

Algorithm formula [5]:

$$v(t) = \begin{cases} \{0.5Vf\,(1 - cos(\frac{\pi t}{T}))\} & 0<t\leq T \\ \{0.5Vf(\,1 - cos\,(\frac{\pi(t-Td-T}{T}\} & T<t\leq T_d \\ \{0\} & T_d<t\leq T_d + T \\ & t>T_d + T \end{cases}$$

## IV. Methodology

Coding is very significant when implementing the artificial intelligence of a real cleaner fish to be programmed and used to mimic in the robotic fish. It will enable the robotic fish to have a false instinct so that it can move around, turn, flip, swim slow, swim fast, and vacuum the trash that is consuming the Fish's habitat. The trash it will suction up would consist of plastic, rubber, and algae. The codes are executed from the computer and then transferred into the robotic fish using a chip and a microprocessor. Coding will also enable the robotic fish to remotely not bump into any objects when searching for trash and to not be destroyed in the process of the experiment. Both code and algorithms would work together to provide stability in movement and control of cleaning the environment. Our project will be sought with two methodologies for code and they are experiments and observations. These methodologies would help determine which codes are resourceful for the robotic fish to have the proper artificial intelligence as a vacuum cleaner fish and allow for the correct replica of fish-like movement. Just like the trials in the algorithm and, kematics, and making the fish design, the code also needs to go through trials. There would be three trial runs for the code [15]. Each of the codes will be written out in Github before the execution process. Also the performance will be evaluated each time the robotic fish cleans the water and how long it takes. The performance of each movement would be compared in each of the trials so see which codes are the best to use to clean underwater at a faster speed [15].

The code will be encrypted so that it cannot be intercepted and decrypted by any hackers. Also another reason for encrypting the code is that so it cannot be manipulated by anyone other than the teammates that are writing the codes. The codes would also initiate the instinct of having camouflage mode in case of any predators. The camouflage mode does not require the robotic fish to temporarily disappear or change colors like an Octopus. However, the camouflage mode would consist of hiding behind seaweed or the rocks in the water. From here this would determine the survival skills of the robotic fish and that if it can coexist among the other fishes in the water.

## V. Preliminary Findings and Research

The team explored various options on how to implement an AI enabled robotic fish. Of these options, garbage collection was chosen as the most viable option.

### *A. Source Code Repository Findings*

The team explored and researched various source code repositories from various sources (i.e. GitHub, GitLab, Azure Repos, etc.), and found that this one was the most viable option: The Waste-classification repo created by techShash [16] provides open-source code that is able to distinguish waste as organic or recyclable which can be useful in many applications such as maintaining clean water sources and improved waste testing by the government and/or private companies (classifying "water junk" as true waste or something that can be recycled and reused in society). The Deep Learning Keras model was employed, containing six Convolutional Layers and two Dense Layers which attributed to 91% model accuracy. Convolutional Layers methodology effectively take subsets of input data and spreads it across the entire spectrum of input volume to compute products between the filter entry points and the actual input, whereas Dense Layers do not use filters and is a linear operation giving specific weights to each of the inputs and outputs.

### *B. Dependencies Libraries Used*

Since the team has chosen coding to be the main method in which we program the robotic fish, some dependencies were needed in order to make the code run properly. The dependencies chosen include; Keras [17], TensorFlow [18], OpenCV [19], PIL [20] and matplotlib [21]. Keras is an API (application programming interface) that is easy to learn and reduces the amount of user actions that are necessary for common use cases. It also integrates with other learning languages like TensorFlow and enables the user to implement anything that can be built in the base language. TensorFlow is an end-to-end platform that allows users to build and deploy machine learning models. TF offers many levels of abstraction to ensure the right one fits the needs of the coder. The function 'eager execution', allows for easy and quick, prototyping and debugging. OpenCV is an open source computer vision library used for machine learning. It contains more than 2,500 optimized algorithms that include, but are not limited to, a wide-ranging set of standard and state of the art computer vision and machine learning algorithms. Python Imaging Library, also known as PIL, adds image processing to out Python interpreters. This library offers a variety of file formatting's support, and it provides a stable foundation for an overall image processing tool. Matplotlib is a library for creating 2D plots of arrays in Python. Its intended use was to simply create plots with as little as one command to a few. It can also, create a histogram of the data that is being used.

### *C. Evaluated Dataset [22]*

Training a machine learning model with the right dataset play a significant role. The dataset decides how efficiently the model is trained and then how accurately it gives results. Dataset that was used to train the model contained a total of 22564 images out of which 12565 images were organic waste items and 9999 images were recyclable waste items. For the purpose of testing 1401 organic waste images and 1112 images of recyclable waste were used making the total images that were used for testing 2513. Approximately 85% of the data was used for training and 15% was used for testing.

### *D. Training Model*

In order for the Robotic fish to classify underwater if it is suction vacuuming garbage or not is based on the back end of TensorFlow. This will authorize the machine learning capabilities for the Robotic fish. The robotic fish will be programmed with code from the Tensor Flor platform to pick up "foreign " objects in the water. This means that objects that are not from the underwater habit. These foreign objects would be like plastic straws, plastic bags, sunglasses, and paper which are easy for the vacuum to suck up without getting clogged.

CNN(Convoluted Neural Network) is the training model or prediction model used to replicate the results from preliminary findings in distinguishing if the foreing objects are garbage or not. The training model is also constructed from the TensorFlow platform as well. The waste would be sorted into different categories in the TensorFlow library for the robotic fish to discover, predict, classified and identify trash with images. The images of the trash are programmed into the artificial intelligence to help the robotic fish identify the waste it has to clean up. CNN will use CIFAR 10 to contain at least "60,000 "images of garbage and underwater trash. These images would be placed into "10 categories with an amount of " 6,000" images in each category [18], as shown in the code snippet below:

```

from __future__ import absolute_import, division,
    print_function, unicode_literals
import tensorflow as tf
from tensorflow.keras import datasets, layers,
    models
import matplotlib.pyplot as plt
# CIFAR 10 Code
(train_images, train_labels), (test_images,
    test_labels) = datasets.cifar10.load_data()
# Normalize pixel values to be between 0 and 1
```

```
train_images, test_images = train_images / 255.0,
    test_images / 255.0
```

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