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# Manufacture of an Underwater Robotic Fish (MURF): A Mechatronic design implementing Carangiform motion

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*Abstract*— **The design, development and control of an underwater fish like robot has been presented in this paper. This robot is capable of maneuvering itself without any manual control using two servo motors and an underwater ultrasonic sensor. The underwater ultrasonic sensor is used to detect the objects in the robot's path and servo motors are used to provide the necessary movement and corresponding positional feedback. This robot's design is focused peculiarly on the carangiform locomotion of fish in order to develop an agile and efficient underwater robot, to achieve quick movement for surveillance, exploration, pollution control and many other applications.**

***Keywords- Underwater robot, Carangiform motion, Robotic Fish, Underwater Ultrasonic Sensor, Servo Motors***

## I. INTRODUCTION

This paper describes the development of an autonomous robotic fish, meant to be used as an experimental platform for the observation and preservation of marine ecosystem. In its development, particular attention has been paid to the system architecture and the Bio-Mechatronics design in order to achieve an agile swimming movement with the help of sensors [1].

To achieve the agile movement, we used the ultra-sonic sensors to measure the existence of obstacles and the distance from the robotic fish to the obstacles [1-2]. With the inference and learning ability of the system, the robotic fish can move away from obstacles freely. It has a structure which uses only two motors to generate fish-like swimming motion using C-bends tail shapes [3].

This paper presents a Mechatronics design of a 3D swimming robotic fish, namely MT1 (Mechanical Tail) robotic fish which can be used as an alternate for underwater vehicles in the areas of surveillance and real time mapping of objects under water [3]. It has a structure which uses only two motors to generate fish-like swimming motion using C-bends tail shapes. This robot is also used for the detection of oil leakages underwater to prevent pollution at the early stage.

This paper is organized as follows: Section II describes the mechanical concepts of the robot. Section III describes the electronics and propulsion of the robot. Section IV concludes the papers with results and future advancements.

## II. MECHANICAL DESIGN

Swimming models of fish are various depended on the types and species of the fish i.e. Eel swims by waving the whole body (anguilliform locomotion), Tuna waves the tail peduncle (thunniform locomotion), Salmon uses both tail and rear body (carangiform locomotion). Furthermore, influenced by the fluid environment, robotic fish's propulsion is concerned with hydrodynamic and is hard to establish purely analytical methods. This means that exact mathematic models are difficult to be applied to specify the whole methodology by plain system. The system architecture of our robotic fish is based on the natural movement of Carp Fish (Koi). The robotic fish consists of modulating joint that propels the body by oscillating the tail peduncle and pectoral fins.

### *A. Locomotion and Movement*

Forces acting on a swimming fish and robotic fish are the essential part of stabilizing and propel the body in fluid environment. The locomotion of fish is compounded from various fundamental factors including the hydrodynamic of fluid environment, apparatus of the marine animals packed with collections of their locomotive styles. Fish swimming mechanism affects surrounding water in any movements. While a fish swims, there is transformation of momentum between the fish and the surrounding water. Majority of momentum arises from fish's locomotion such as lift, drag, acceleration. Other behavioral locomotion creates momentum transformation including cruising, propulsion, and maneuvering forces are distributed in the fish body as shown in Figure 1.

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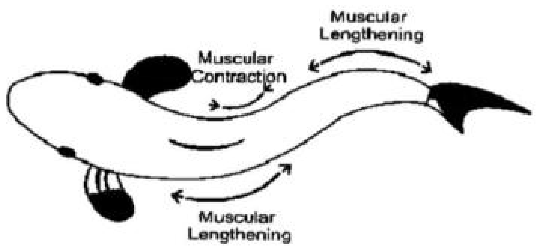


*Figure 1: Fish Locomotion*

When fish bends its body, it creates the muscular contraction and lengthening which generates the propulsive wave of water passing backwards along the body segment and propels the fish forwards. The force contributed from its small body segment creates the momentum of passing water that called the reacting force (FR). The reacting force is the propulsion element that could be analyzed into a lateral force (FL) and a thrust force (FT) component. The forward propulsion is produced from the thrust force component (FT). While the lateral force component (FL) produces the tendencies for the anterior part of the body to side slip and yaws the body along its vertical axis. This lateral force causes significant energy loss in fish motion. Figure 2 shows the swimming mechanism created by the reacting force of the fish motion. The thrust force will increase if the fish could generate larger propulsive wave, thus, the tail peduncle must traverse greater distance (wider swing-angle) with higher oscillation frequency. [4] proposed a principle in which another NN yield input control law was created for an under incited quad rotor UAV which uses the regular limitations of the under incited framework to create virtual control contributions to ensure the UAV tracks a craved direction. Utilizing the versatile back venturing method, every one of the six DOF are effectively followed utilizing just four control inputs while within the sight of un demonstrated flow and limited unsettling influences.

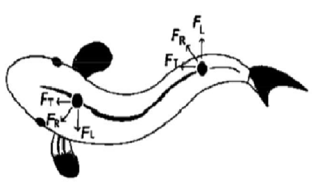


*Figure 2: Nodal Forces on Fish Skeleton*

Marine animals' behavioral movement and locomotion are naturally fascinated and various. We employ the carangiform swimming mode with the robotic fish. The carangiform mode performs the major movement at the very end of the body and tail in order to drive forwards. In the caudal part, the oscillation caudal in or tail peduncle has to flap rapidly. Fish starts its motion by bending its rear-half body [Figure3], and then it moves the caudal fin closer to the body. Fish bends the body in to a tight 'C' shape to create the momentum of passing water that generates the reacting force (FR) to propel forwards. Finally, the body releases and straightens into the direction of the tail peduncle. This "C" shape movement is a common locomotion for carangiform swimming mode of a fish. Fish body segmentation is the essential part that will lead to model the fish maneuvering and design of our robotic fish.

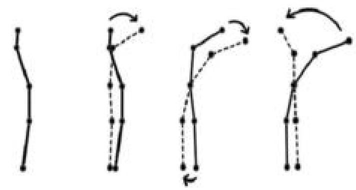

*Figure 3: C shaped movement*

*B. Design of Robotic Fish*

Parametric Creo is a kind of design software which is easy to learn and handle. It allows the user to design complex mechanical structures in 2D and transform them into 3D parts. In this way, it's not require to bother the users to redesign and suit the beginners' fine. By using Parametric Creo, we can design all parts of the body quickly, such as, the head, the trunk, the tail and the fins. Figure 4 shows the skeleton of the multi-joint robotic fish drawn by Parametric Creo.

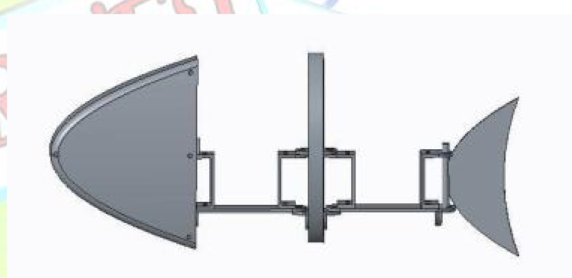

*Figure 4: 3D diagram of robotic fish skeleton*

*C. Manufacture of Robotic Fish*

The fish model was made by bending and welding mild steel sheet metal. This weld was made by TIG welding. Gas tungsten arc welding (GTAW), also known as tungsten inert gas (TIG) welding, is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by an inert shielding gas (argon or helium), and a filler metal was used, though some welds, known as autogenous welds, do not require it. A constant- current power welding supply produces electrical energy, which is conducted across the arc through a column of highly ionized gas and metal vapors known as plasma.

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The process grants the operator greater control over the weld than competing processes such as shielded metal arc welding and gas metal arc welding, allowing for stronger, higher quality welds. However, GTAW is comparatively more complex and difficult to master, and furthermore, it is significantly slower than most other welding techniques. Further, the tail portion was cut. Then the guide ways were milled from mild steel, for the smooth operation of the tail to move.

*Figure 5: Parts after Fabrication*

## III. ELECTRONIC DESIGN

Various electronic components used are Atmel microcontroller Atmega328 and regulator. Sensors used are Temperature sensor, pH sensor, Ultrasonic sensor and a Camera for surveillance. Actuators used are high torque servo motors. Power is supplied to robot using a LiPo battery.

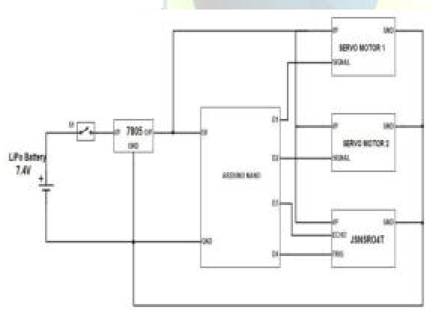


Figure 6: Circuit Design

A. Embedded Control System
AVR microcontroller ATMega328 is used as central processing unit for the robot. It is equipped with timers/counter, ADC, interrupts, Flash memory and USART. It is an 8 bit controller with 32Kbyte of flash memory. To power up the ATMega328 and other components, a voltage regulator IC7805 that serves as a smoothening circuit to generate regulated 5v power supply is used. B. Sensors and Actuators Servo motors which are advantageous over DC motors for this application are used for propulsive mechanism. The angles of servo motors are controlled by PWM signals generated by Microcontroller. The speed of robotic fish is controlled by the frequency and the amplitude of oscillations. For Dive In mechanism, Pump and DCV are used. They are driven by a driver circuit satisfying the need of current. Both Pump and DCV are powered by 12V supply.

A pH sensor is used to measure the pH of the water. A pH probe is a single cell battery with a very high resistance, where the voltage produced is proportional to the hydrogen ion concentration around the probe and therefore proportional to the Log of the hydrogen ion concentration based on the expression,

□□ = −□□□ (□□)

That is when the concentration is greater on either side of the probe, the ion flow will induce a slight voltage between the probes electrodes, this voltage can swing both +/- which will indicate either an acid or base. This sensor provides an analog output. A built-in ADC of controller converts these signals to digital. These data are transferred to base station through the wireless communication link.

A temperature sensor is used for the measurement of temperature under the surface of water. A DS18B20 waterproof digital thermometer is used here. It provides 9-bit to 12-bit Celsius temperature measurements unique 1Wire Interface that requires Only One Port Pin for Communication (which requires only 1 wire for receiving and transmitting data) apart from which a ground line is also required. A multiplier of 0.0625 is a conversion coefficient between sensor's internal values and real temperature.

An Ultrasonic sensor Jsn-sr04t integrated with wire enclosed waterproof probe is used for the detection of the obstacle and alter the speed of the robot correspondingly.

The Robotic Fish is provided with a camera. The underwater camera helps in underwater surveillance and monitoring. For underwater camera, isolated transmission and reception system is provided.

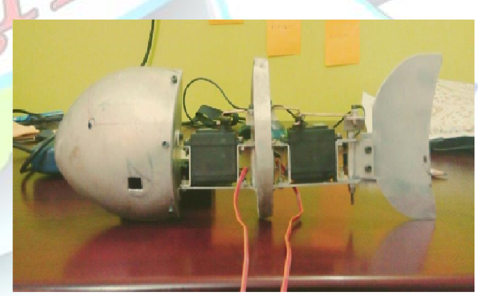

Figure 7: Assembled Model

## CONCLUSION

The project describes the design and total structure of well working Robotic Fish. The work has resulted in a well-functioning and low cost underwater robot that can successfully navigate inside the water performing different activities like underwater surveillance, temperature sensing, etc. It is a mechanical system with simplicity and symmetry being two prime aspects sought in the design. The two servo motors that provide propulsion, allow the robot to actively control degrees of freedom and also help to mimic the real fish motion.

The future work will focus on more number of actuators in oscillatory propulsive mechanism to achieve greater

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closeness to actual fish movements. It also focuses on developing a single mode of communication between robotic fish and base station overcoming the difficulties in change of medium.

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