Robofish

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Abstract

The study of biomimetics is largely driven by the desire to integrate design advantages found in the natural world to experimental devices and, ultimately, practical machines.

The work contained herein consisted of the construction of a biomimetic robotic fish as a functional experimental apparatus. An experimental process is to obtain fish swimming.The present research has focused on the relevance of Lighthill (LH) based biomimetic robotic propulsion.The objective of this paper is to mimic the propulsion mechanism carangiform swimming style to show the fish behavior navigating efficiently distances at impressive speeds and its exceptional characteristics.The robotic fish model (kinematics and dynamics) is integrated with the Lighthill (LH) mathematical model framework.. A comprehensive propulsion mechanism study of the different parameters namely the tail-beat frequency(TBF), the propulsive wavelength, and the caudal amplitude are studied under this framework. Yaw angle study for the underwater robotic fish vehicle is also carried out as it describes the course of the robotic fish vehicle.TBF is found to be the effective controlling parameter for the forward speed of the vehicle over a wide operating conditions.

Keywords: *Biomimetic, Robotics, structure of fish(model) ,task synchronization.*

Introduction:

With the advent of the bio-inspired underwater vehicle/robots applications, finding an efficient propulsion mechanism is of the utmost importance. Sir J Lighthill (LH) mathematical slender body swimming model plays a vital role to envisage the propulsion mechanism of such a biomimetic
robotic fish. Exploring the spatial locomotion of certain aquatic vertebrates that are able to travel at surprisingly remarkable speeds, has been the interest of researchers towards the contribution of the bio-inspired robotics or bio-mimetics and has been continuously increasing through the last decade.

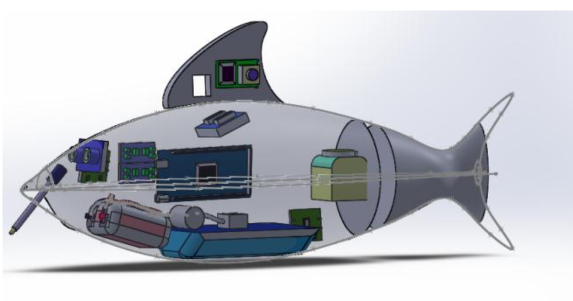
Biomimetics reflect the features and capabilities of natural evolution of a system that could be efficiently replicated or mimicked in a human engineered system to design of new technologies and improvement of conventional ones. One of the focused technologies has been the development of
autonomous underwater vehicles as a greater part to the increasing interest in unmanned underwater surveillance and monitoring. Of particular interests are regions of the underwater environment, underwater detection, pollution source tracking, underwater archaeology, search and rescue, and so forth.

The propeller based locomotion although rendered the initial answers to underwater locomotion but sets issues on high-maneuverability and efficiency. The scientific community and researchers also found that propeller-strikes produce
greater amount of marine debris, marine creatures mortality and shallow waters ecosystem disturbances. Biomimicked or fish-like robots are expected to be quieter, more maneuverable (lesser accidents), and possibly more energy efficient (longer
missions). Undulating-finned robot can preserve undisturbed condition of its surroundings for data acquisition and ex-ploration (stealth). Movement of fish through water without
creating ripples and eddies were more reasons to choose abio-inspired design for underwater locomotion. Considering the propulsive features of existing fish modes, a novel propulsive mechanism that integrates fish-like swimming with modular links and fin movements has been proposed .

In 2004, Shinjo and Swain proposed a preliminary design of a biologically inspired Oscillatory Propulsion System using SMA. The use of elastic systems in the scombrid propulsion system was investigated. The activation timing and duration of individual actuators are controlled by a microprocessor. Each actuator is equipped with a simple driver circuit to activate the SMA wires. They adapted a simplified geometry of muscular systems and axial tendons for this design, which alleviate the limited strain of the SMA by trading force for distance and provide an effective force transmission pathway to the backbone .

In 2010, Chen *et al* proposed a physics-based model to predict the steady-state cruising speed of the IPMC-based robotic fish. An IPMC-based robotic fish prototype was developed to test this model. IPMC-based robotic fish was designed to be fully autonomous and serve as a mobile sensing platform, which consists of a rigid body and an IPMC-based caudal fin. A passive plastic fin is used to enhance propulsion. A custom-made rigid shell is employed to reduce the contact surface (or drag force).

In 2005, Kim *et al* presented a wireless undulatory tadpole robot using IPMC-based actuators. A biomimetic undulatory motion of the fin tail is implemented to improve the thrust of the tadpole robot.



Solid work design of RoboFish

How Fish Swim

A great deal of study has been conducted on the manner and modes of swimming marine creatures from both a life sciences point of view as well as an engineering perspective. Fish, in general, swim one of two ways; thrust is either generated by periodic movement of some portion of the creature's main body, or by any of a number of mechanisms involving the creature's median and pectoral fins [60]. The former method of propulsion, termed body and caudal fin locomotion, is utilized by an estimated 85% of fish families and will be the focus of this study because of its use by fast and efficient swimming fish species. Median and pectoral fin swimming is favored by species that swim slowly and are required to be highly maneuverable.There are four modes of swimming that fall under the method of body and caudal fin locomotion; anguilliform – whole body undulation, subcarangiform – undulations confined to final half of body, carangiform – undulations confined to final third of body, and thunniform –undulations confined the caudal fin and peduncle only. Scientists have identifiedtwo primary phenomena at work during fish swimming that are responsible for propulsive thrust. The first is an added-mass effect whereby the fish body imparts momentum to the water directed backward and an equal opposing force is exerted on the fish propelling it forward. The second is a vorticity effect whereby the vortices in the fish body's own wake impart a propulsive force, as the vortices in the fish's wake have a rotation and effect opposite that of a classical drag inducing Karman vortex street.

Swimming effort also determines the top speed of the fish. Shukla and Eldredge studied the effect swimming effort has on the speed of a fish and found that as long as the speed of wave propagation down the tail is greater than the swimming speed of the fish, thrust is produced.In reality, at ultimate swimming speed, the tail wave speed is greater than the speed of the flow around the fish as the forces on the body are balance by drag.

Tail Motion Modeling

Before a mechanical design for an oscillating foil propulsor can be synthesized, first a basis for motion modeling and control of the propulsor elements must be established to ensure the propulsor will be feasible to build as well as effective. In 1960 M.J. Lighthill published an influential paper that proposed a mathematical model for fish tail motion based on his observations on slender fish. The equation he proposed was:

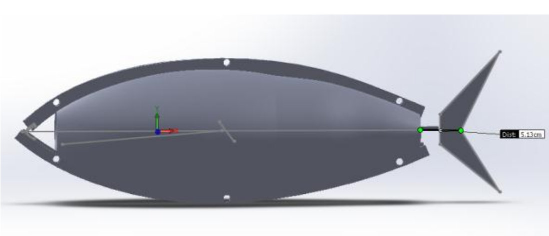
$$y = f_B(x, t) = (c_1 x + c_2 x^2) \sin(kx + \omega t)$$

where y equals the lateral displacement of the tail from the undulation center, c_1 and c_2 are unknown coefficients, x is the location on the tail, k is the body wave number which equals two times pi divided by the tail length, ω is the tail beat frequency, and t is the time elapsed [38]. This equation has been one of the foundation stones for much of the work conducted on fish-like locomotion since.

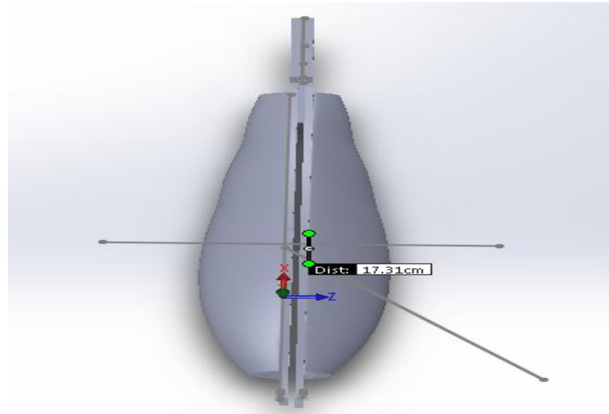
Fish are vertebrates with a spinal column made up of many small bone segments and connective tissue. Mimicking this with an artificial mechanism is problematic; the mechanical links are almost sure to be longer than the individual fish vertebrae, so the mechanical fish tail inherently lacks the flexibility of an actual fish. In the construction of an artificial fish tail, the minimizing of tail link size and the use of numerous links will allow the artificial fish tail to better fit the sinusoidal curves of actual fish motion.

System model

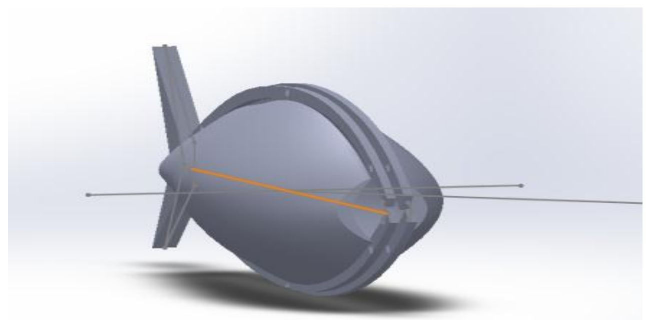
The Fish locomotion is approximated using a 3-link (including the pectorals attached to the head) mechanism with two actuated joints. The first link as the "head", second link as the body is roughly two-thirds of the weight of the entire robot. The tail of the robot is formed by the third link connected to the caudal fin. Moreover, the caudal peduncle and fin have been rendered in to a Thunniform (shark)semi-crescent structure for an efficient thrust and therefore to allow high cruising speed for longer period of time .While the kinematics study explains the geometry of the motion of robofish w.r.t a fixed reference coordinate frame as a function of time, the dynamics of any rigid body [6] can be completely described by the translation of the centroid and the rotation of the body about its centroid.This leads to the ability to derive the actuator torques necessary to produce the tail motion that is desired. The present research work investigates into the system modeling as a 2-joint, 3-link manipulator based mobile vehicle, with Denavit-Hartenberg (DH) Kinematics Model and Lagrangian Dynamics Model.



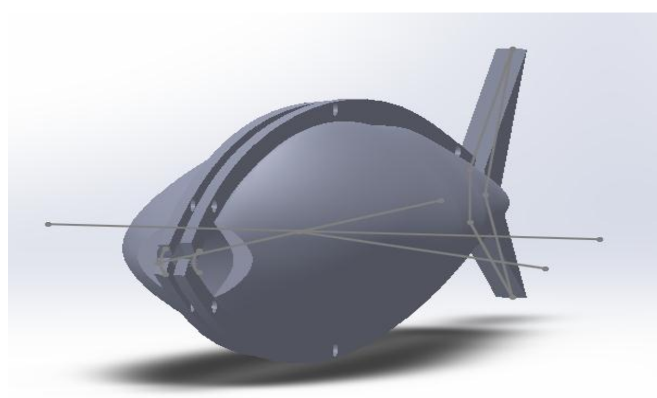
1)SIDE VIEW



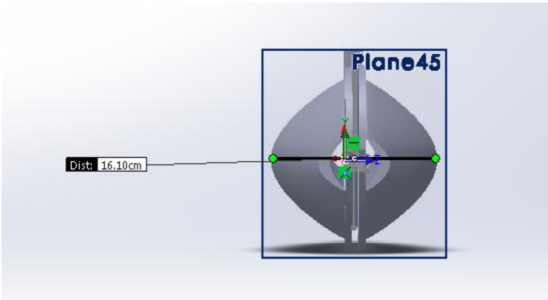
2)TOP VIEW



3)ANGLE 60



4)ANGLE 120

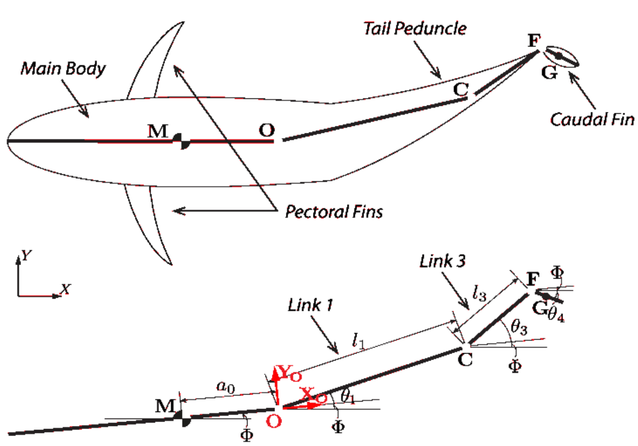


5)BACK VIEW

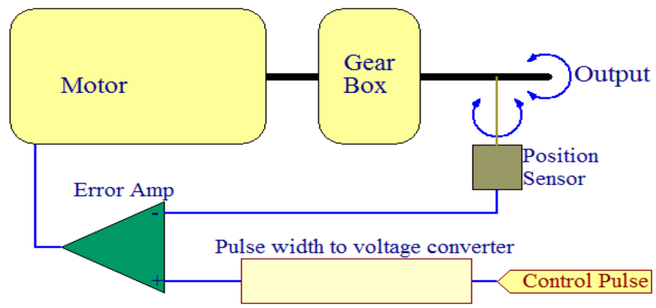
Experimental Program

For the experimental program to be executed, a free swimming biomimetic fish robot must be developed consisting of a hull, actuated fish tail, control surfaces, electronics and software. The purpose of the hull is to provide a water tight vessel to for the electronics package and act as the major structural element tying the other machine elements together. The actuated fish tail provides the propulsive force driving the robot.

The control surfaces enable directional control of the fish. The electronics package consists of a controller, batteries, and radio control receiver and handles the time varying location of the tail links and the communication with the land based radio transmitter. The robot software will act as operating system on the controller and set the states of the various tail link actuators and the control surface actuators.



he robot's tail must be constructed with as many links as practical so that the continuous curve produced by Lighthill's equation can be adhered to with a minimum of error.The tail constructed used PVC as the structuralmaterial and five direct acting standard sized hobby servomotors for actuation, one servomotor for each link.



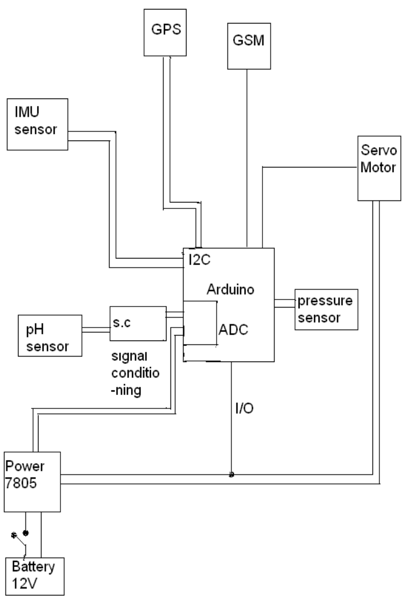
The servomotors are standard sized, high torque, quick response drivers. They werenot originally intended for submersible use; each servomotor has been packed with dielectric grease to harden it against water intrusion.

Control Hardware

The robot's control system should be sophisticated enough to accurately model fish swimming as defined by the state matrices. For this purpose, a microcontroller of sufficient processing speed must be chosen and it must have associated with it enough memory capacity to contain the program modules required to set all the various servomotor states.

[The controller selected for the project is an Innovation First Robot Controller (IFRC). It encompasses a Microchip PICmicro® 18F8520 microcontroller and 32 kb of memory. The 18F8520 microcontroller is capable of 10 million instructions per second,which exceeds project requirements. The IFRC is equipped with eight PWM outputs, and since the construction of the robot requires seven, it is suitable for use.The IFRC is programmable in C coding language, and programs are uploaded via a RS232 port]

Communication with the robot is also a requirement of the project, as the fish will not be autonomous because the data collection strategy requires it to complete a veryspecific task. Autonomous control is an option for the future, but for these experimentsthe robot will be teleoperated from land using a 75 MHz radio transmitter and receiver, or even can use GSM or GPS module for communication



SYSTEM BLOCK DIAGRAM

Conclusion

The present paper deals with the study, implementation and analysis of Lighthill mathematical model based real time design of a biomimetic fish like underwater vehicle The system uses DC servomotors as actuators and the controller bed is Arduino platform. A systematic and scientific approach of system modeling and integration has been presented with the robotic-fish. and structural CAD design in Solidworks. The up-gradation of the servos and the optimization of the robotic fish has to be performed in the subsequent stages of the development of this project

A biomimetic carangiform robotic fish has been constructed as a functional experimental apparatus. The robot constructed possesses a propulsive section with five short links capable of fitting the sinusoids produced by Lighthill's model of fish tail motion with commendable accuracy. This robot is of solid construction suitable for heavy usage, is capable of pitch and yaw control, is nearly neutrally buoyant, and allows for expansion in features such as the inclusion of analog and digital sensors. It is viable for use in future work involving aquatic mobile robotics research.

Future work that should be considered for completion on the robot fish apparatus itself is the addition of a fleshy covering for the tail section, to determine if propulsive force could be improved by preventing fluid flow lines from crossing the tail linkage.

Autonomous control could be added to the robot so that it could conduct experiments on its own, removing the need for a person in the tank to stage it and the need for a strong signal from a land based radio transmitter.

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