A SURVEY PAPER ON ELECTROMATED FISH FOR UNDERWATER SURVEILLANCE

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***Abstract*—This paper presents the design and construction of an Electromated fish prototype which resembles a natural fish. The term Electromated stands for "Electronically Automated". The design procedure, adapts a bio-inspired approach, which uses the physical characteristics of a real fish as its size and structure. The Electromated fish is more competent than current AUVs (Autonomous Underwater Vehicles) propelled by motion because the fish is a paradigm of bio-inspired AUV. The Electromated Fish can operate in complex environments. They can not only perform underwater exploration and discover new species, but they can also salvage and set up underwater facilities. When operating in dangerous environments, Electromated Fish display a heightened performance when compared to other machines.**

The Electromated fish is propelled with the help of two Undulatory Fins inspired by the locomotion of Rays and Cuttle fish. Each fin mechanism is comprised of individually actuated fin rays, which are interconnected by elastic membrane. On board microcontroller generates the motion pattern that results in fin undulations due to which propulsion is generated. The UUV fabricated will be controlled wirelessly. The Body portion consists of electronic components with leak proof and handles the fin propulsion. An attempt has been made to develop an Electromated fish with improved manoeuvrability (movements) and performance features.

I. INTRODUCTION

The fishes are the best natural swimmers in the world. They are so adapted to their environment that, they excel in their high manoeuvrability (movements), fast swimming and sudden acceleration in nature. A fish-like underwater robot, which has flexible tail mechanism, can swim faster and more quietly with lower consumption and higher manoeuvrability in water. A robotic fish design provides versatile solutions for various different marine applications, such as examination of under water resources, determination of pollution, observation of living forms, checking the quality of water, survey of submerged areas, fault detection in electricity or oil pipelines, coastline security and military

missions, it can provide live videos of the surrounding, it can mainly be used for area monitoring to check if the particular

area is safe for the humans to jump to do a scuba diving. It can also be used for obstacle detection and alerting it.

There are two basic approaches in robotic fish design. First is the biomimetic design which has certain requirements such as a tail with the size and number of joints to provide body travelling wave, and the ability to stay at a certain depth with the control of the centre of gravity. The second design approach uses only the movement effects of fish, but it is not physically inspired by real fish.

II. LITERATURE REVIEW

In the paper titled, "Fish-like swimming prototype of mobile underwater robot." Malec et al. designed three-link Cyber Fish by focusing on BCF (bodies caudal fins)-like locomotion. The prototype was produced by using acrylic, rubber, aluminum and stainless steel. In the referred work, the angle of the pectoral fins associated with the servomotor is changed to provide up-down motions as sharks. [4]

In the paper titled, "Design, fabrication, and swimming performance of a free-swimming tuna-mimetic robot." Masoomi et al. used 3D-printing technology in order to construct the tuna-like robotic fish with a main body and flexible tail mechanism. The robot surface was covered with epoxy to provide waterproofness. The dynamic behavior of the fish robot is influenced by two main forces: hydrostatic and hydrodynamic forces. Hydrostatic forces are more essential for depth control while hydrodynamic ones are used for swimming. However, to facilitate the swimming model with minimum energy dissipation, hydrodynamic forces need to be produced with respect to several factors. These factors are introduced as optimal swimming factors. [5]

In the paper titled, "Design of Robotic Fish for Aquatic Environment Monitoring" Anuradha A. Maindalkar and Saniya M. Ansari, smartphone based aquatic debris monitoring robot design is proposed and discussed. Regularly monitoring aquatic waste or debris is of more interest to the environments, aquatic life, human health, and water transport. This paper presents the design of a robotic fish system that integrates an Android smartphone and a robotic fish for debris monitoring. The smartphone based aquatic robot can accurately detect debris in the presence of various environments. [6]

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FORCES ACTING ON AN UNDERWATER VEHICLE:

Several forces act on an underwater vehicle that require consideration for the design process. These include buoyancy, hydrodynamic damping and added mass. Buoyancy is one of the most important factors which significantly affects the vehicle's ability to submerge as well as its stability. Stability is also affected by external forces. Pressure is another significant factor for underwater vehicles that needs to be taken into consideration in the design process.[1][3]

Buoyancy:

The magnitude of the buoyant force, B, exerted on a body, floating or submerged, is equal to the weight of the volume of water displaced by that body. The ability of an object to float depends on whether or not the magnitude of the weight of the body, W, is greater than the buoyant force. Clearly, if $B > W$, then the body will float, while if $B < W$ it will sink. If B and W equate, then the body remains where it is.

Hydrodynamic Damping:

When a body is moving through the water, the main forces acting in the opposite direction to the motion of the body are hydrodynamic damping forces. These damping forces are mainly due to drag and lifting forces, as well as lineal skin friction. Damping forces have a significant effect on the dynamics of an underwater vehicle which leads to nonlinearity. Lineal skin friction can be considered negligible when compared to drag forces, and therefore, it is usually sufficient to only take into account the latter when calculating damping forces.

Stability:

Assuming no water movement, the stability of a static body underwater is predominantly affected by the positions of the centres of mass, CM, and buoyancy, CB. The centre of buoyancy is the centroid of the volumetric displacement of the body. If CM and CB are not aligned vertically with each other in either the longitudinal or lateral directions, then instability will exist due to the creation of a nonzero moment. If CM and CB coincide in the same position in space, the vehicle will be very susceptible to perturbations. Ideally, the two centroids should be aligned vertically some distance apart from each other with CM below CB. This results in an ideal bottom-heavy configuration with innate stability. In the case of a dynamic underwater body, stability is affected not only by the centres of mass and buoyancy, but also by factors such as external forces and centres of drag. To increase dynamic stability, the centres of drag, determined by the centroids of the effective surface areas of the vehicle, should be aligned with the centres of the externally applied forces. In this manner, the vehicle will not tend to exhibit undesirable characteristics in its motion.

Added Mass:

Another phenomenon that affects underwater vehicles is added mass. When a body moves underwater, the immediate surrounding fluid is accelerated along with the body. This affects the dynamics of the vehicle in such a way that the force required to accelerate the water can be modelled as an added mass. Added mass is a fairly significant effect and is related to the mass and inertial values of the vehicle

Environmental Forces:

Environmental disturbances can affect the motion and stability of a vehicle. This is particularly true for an underwater vehicle where waves, currents and even wind can perturb the vehicle. When the vehicle is submerged, the effect of wind and waves can be largely ignored. The most significant disturbances then for underwater vehicles are currents. In a controlled environment such as a pool, the effect of these environmental forces is minimal.

Pressure:
As with air, underwater pressure is caused by the weight of the medium, in this case water, acting upon a surface. Pressure is usually measured as an absolute or ambient pressure; absolute denoting the total pressure and ambient being of a relativistic nature. At sea level, pressure due to air is 14.7psi or 1 atm. For every 10m of depth, pressure increases by about 1atm and hence, the absolute pressure at 10m underwater is 2atm. Although linear in nature, the increase in pressure as depth increases is significant and underwater vehicles must be structurally capable of withstanding a relatively large amount of pressure if they are to survive.

Propulsion:
Some sort of propulsion is required on all AUVs and is usually one of the main sources of power consumption. When travelling at a constant speed, the thrust produced is equal to the friction or drag of the vehicle, that is,

Thrust = Drag = 12**s2*Acd

Where ρ is the water density, s is the speed, A is the effective surface area and Cd is the drag coefficient. Power consumption for the propulsion system increases dramatically as the speed of the vehicle increases. This is because the thrust power is equal to the product of the thrust and the speed, meaning thrust power is a function of speed cubed,

Thrust Power = Thrust × s = 12**s3*Acd

Therefore, because of an AUV's limited energy supply, it must travel at a speed that does not draw too much power, but at the same time does not take too long to complete its mission.

Submerging:
In the case of a submersible vehicle, since the volume of the vehicle remains constant, in order to dive deeper, it must increase the downward force acting upon it to counteract the buoyant force. It can accomplish this either by increasing its mass via the use of ballast tanks or by using external thrusters. Ballasting is the more common approach for submerging. This method is mostly mechanical in nature and involves employing pumps and compressed air to take in and remove water. The alternative is to use thrusters that point downwards. This is a much simpler system, but is quite inefficient in terms of power consumption and not really suited at great depths. To reduce the size of ballast tanks or the force required by thrusters for the process of submerging, AUVs are usually designed so as to have residual buoyancy. That is, the weight of the vehicle is made to be more or less equal to the buoyant force.

III. PROJECT OBJECTIVES

The main objectives of the project considering the advantages and the disadvantages of the conventional fish prototypes, limiting the scope to problem definition are:-

1. To reduce the damage caused to the aquatic ecosystem by eliminating thrusters and fans and replace them with bio-inspired fin propulsion systems.

2. To reduce the sediment disruption i.e., less disturbance to the marine ecosystem by reducing the thrust forces and driving forces of the servo motors.
3. It is equipped with a camera, it can record the resources present in depths of the water.
4. With its precise manoeuvrability the fish can be used in under water maintenance and Structural inspection.
5. With the help of fin propulsion system the fish has a large scope in stealth operations.
6. To make a cost efficient underwater vehicle.

IV.PROBLEM STATEMENT

The problem is limited to a confined environment as the research is still in its initial stage:-

1. Currently the UUVs which are propelled by the thrusters cause a considerable amount of sediment disruption i.e. transport of sediment at the seabed to different areas causing a disturbance in the marine ecosystems.
2. The conventional UUVs are not suitable for movement in any of the marine ecosystems as the design of the conventional UUV require the thrusters and motors to be present open to the water. The fans or the propellers that are exposed to the sea water is a serious cause for the death of marine organisms.
3. Research suggests that any vehicle which mimics the movement of biological species tend to show more efficiency and better manoeuvrability than the conventional prototype.
4. Conventional UUVs are costlier to design and fabricate.

V.PROPOSED SYSTEM

The AUV appears like a torpedo in many aspects. It consists of a propulsion system having one or two fins, control surfaces that control the movement of the vehicle, a streamlined fairing for reducing hydrodynamic drag and a pressure hull to contain power electronics. The vehicle carries its own energy source, and is programmed with instructions capable of carrying out underwater mission without assistance from an operator. The instructions include information required for navigation between pre-determined geographic positions, measures to be undertaken in case of equipment breakdown, procedures for payload device operation and methods to avoid obstacles. Pre-dive check of the AUV is conducted before starting the underwater mission. The vehicle is submerged into the water and released to start the mission. In some missions, the collected sensor data has to be sent to the operator to ensure that the data is of high quality. In such cases, telecommunications network is provided for this purpose. The vehicle travels to its pre-determined endpoint at the end of its mission and the data is retrieved from the vehicle.

VI. METHODOLOGY

PROPULSION SYSTEMS OF UUV

There are a couple of propulsion techniques for AUVs. Some of them use a brushed or brush-less electric motor, gearbox, Lip seal, and a propeller which may be surrounded by a nozzle or not. All of these parts embedded in the AUV construction are involved in propulsion. Other vehicles use a thruster unit to maintain the modularity. Depending on the need, the thruster may be equipped with a nozzle for propeller collision protection or to reduce noise submission or it may be equipped with a direct drive thruster to keep the efficiency at the highest level and the noises at the lowest level. Advanced AUV thrusters have a redundant shaft sealing system to guarantee a proper seal of the robot even if one of the seals fails during the mission.

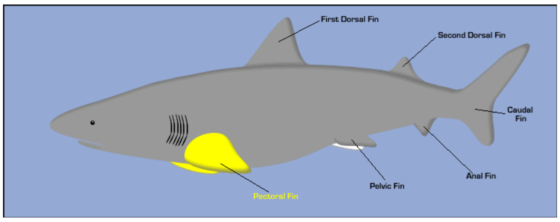


Fig: Fin Propulsion of UUV

FIN PROPULSION

Fish locomotion is the variety of types of animal locomotion used by fish, principally by swimming. This however is achieved in different groups of fish by a variety of mechanisms of propulsion in water, most often by wavelike movements of the fish's body and tail, and in various specialised fish by movements of the fins. The major forms of locomotion in fish are anguilliform, in which a wave passes evenly along a long slender body; sub-carangiform, in which the wave increases quickly in amplitude towards the tail; carangiform, in which the wave is concentrated near the tail, which oscillates rapidly; thunniform, rapid swimming with a large powerful crescent-shaped tail; and ostraciiform, with almost no oscillation except of the tail fin. More specialised fish include movement by pectoral fins with a mainly stiff body, as in the sunfish; and movement by propagating a wave along the long fins with a motionless body in fish with electric organs such as the knife fish.

TYPES OF FIN PROPULSION:

There are two major types of fin propulsion systems. They are:-

1. Oscillatory Fin propulsion
2. Undulatory Fin Propulsion

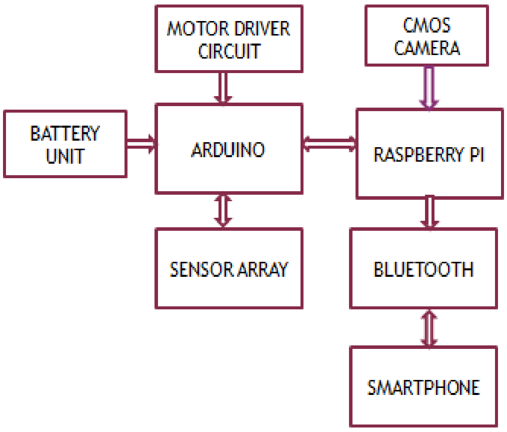
Oscillatory Fin propulsion – In oscillatory motions the propulsive structure swivels on its base without exhibiting a wave formation. In simple terms, the oscillatory fin propulsion systems have fins that oscillate perpendicular to the hull axis but parallel to the hull plane. This type of fin propulsion systems can be easily observed in sharks.

Fig : Oscillatory Fin Propulsion

Undulatory Fin Propulsion - Undulatory motions involve the passage of a wave along the propulsive structure. In other terms, the undulatory fin propulsion system uses fin that move along a sinusoidal path parallel to the hull axis but perpendicular to the hull plane. These type of fin propulsion can be easily observed in Manta Rays and Sting Rays

Fig : Undulatory Fin Propulsion

VII. BLOCK DIAGRAM



Raspberry Pi:

The Raspberry Pi is a series of small single-board computers developed in the United Kingdom by the Raspberry Pi Foundation. The Raspberry Pi model used in the project is Raspberry Pi (Model B+). The specifications of it is Core Broadcom BCM2835 & ARM11 SoC Core Architecture. The board is simulated using the Raspbian Operating Software. The Raspberry Pi here is used for controlling the CMOS Camera.

Arduino:

Arduino is an open-source platform used for building electronics projects. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on the computer. The type used here is Microcontroller ATmega328. It is used to control the servo motors. The software tool used for simulating it is the Arduino software itself.

CMOS Camera:

CMOS (complementary metal oxide semiconductor) sensors are used to create images in digital cameras, digital video cameras &digital CCTV cameras. The optical technology is used in machine vision for robots. The CMOS Camera has a resolution support for 640x480x1600x1200. The purpose of using the CMOS Camera is to record the video of the underwater environment.

Bluetooth:

The Bluetooth model used is Bluetooth HC-05. The HC-05 module is an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. Serial port Bluetooth module is fully qualified Bluetooth V2.0+EDR (Enhanced Data Rate) 3Mbps Modulation with complete 2.4GHz radio transceiver and baseband.

Battery Unit:

The battery unit used is lithium polymer battery. It is also called as correctly lithium-ion polymer battery (abbreviated as LiPo, LIP, Li-poly, lithium-poly). It is a rechargeable battery of lithium-ion technology usig a polymer electrolyte Instead of a liquid electrolyte. High conductivity semisolid (gel) polymers form this electrolyte. These batteries provide higher specific energy than other lithium battery types and are used in applications where weight is a critical feature, like mobile devices and radio-controlled aircraft.

Sensor Array:

The sensor array consists of accelerometer, Ultrasonic distance sensor, and the Gas Sensors. The accelerometer used is ADXL335 which is a 3 axis sensing device. The Ultrasonic distance sensor used is HY-SRF05 which is a two channel logic level converter. The gas sensor used is MQ-3.

Propulsion Using Servo Motors:

For sine wave generation servo motors are used. They are small in size but pack a big punch and are very energy-efficient. Inside there is a pretty simple set-up: a small DC motor, potentiometer, and a control circuit. The motor is attached by gears to the control wheel. As the motor rotates, the potentiometer's resistance changes, so the control circuit can precisely regulate how much movement there is and in which direction. Servos are controlled by sending an electrical pulse of variable width, or pulse width modulation (PWM), through the control wire. There is a minimum pulse, a maximum pulse, and a repetition rate. A servo motor can usually only turn 90° in either direction for a total of 180° movement. The motor's neutral position is defined as the position where the servo has the same amount of potential rotation in the both the clockwise or counter-clockwise direction. The PWM sent to the motor determines position of the shaft, and based on the duration of the pulse sent via the control wire; the rotor will turn to the desired position. The servo motor expects to see a pulse every 20 milliseconds (ms) and the length of the pulse will determine how far the motor turns. For example, a 1.5ms pulse will make the motor turn to the 90° position. Shorter than 1.5ms moves it in the counter clockwise direction toward the 0° position, and any longer than 1.5ms will turn the servo in a clockwise direction toward the 180° position.

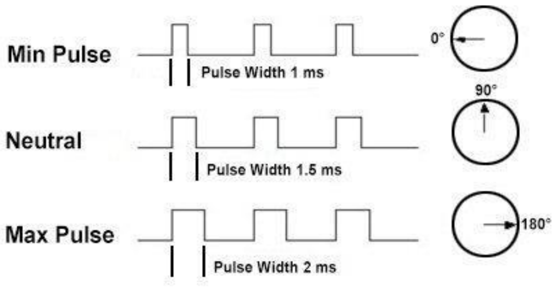


Fig: Pulse Width at different angles

COMMUNICATION SYSTEM :

The purpose of the communications system for the fish is essentially to provide operators with the ability to remotely transmit and receive data from the vehicle in order to perform testing with greater ease. Communication with the vehicle was needed to perform testing and system identification.

To communicate with the fish controller, a Bluetooth dongle was attached to one of the serial ports of Controller.

This system allows:

• Stored data to be uploaded to a computer

• Signals to be sent to the fish during test runs

This system, however, does not work in more than 2m of water, and hence, can only be used to transmit and receive in the testing phase

HC-05 BLUETOOTH MODULE:

The Bluetooth module HC-05 is a MASTER/SLAVE module. By default the factory setting is SLAVE. The Role of the module (Master or Slave) can be configured only by AT COMMANDS. The slave modules cannot initiate a connection to another Bluetooth device, but can accept connections. Master module can initiate a connection to other devices. The user can use it simply for a serial portreplacement toestablish connection between MCU and GPS, PC to your embedded projects.

VIII. CONCLUSION

This study presents the biomimetic design and construction of the Electromated fishprototype based on bio-inspired swimming to perform real-world exploration and surveymissions. The developed robotic fish mimics the natural fish swimming modes with two-linktail mechanism. This fish can serve as one of the best UUV (Unmanned Underwater Vehicle). It can be used for multiple underwater applications. Since the approach is a bio-inspired one and resembles a natural fish, the other aquatic creatures won't be frightened by this artificial vehicle.

IX. SCOPE OF THE PROJECT

The robotic fish has several applications that's can be achieved in the future. It can serve many applications. These applications may be examination of under water resources, determination of pollution, observation of living forms, checking the quality of water, survey of submerged areas, fault detection in electricity or oil pipelines, coastline security and military missions, providing live videos of the underwater environment, it can mainly be used for area monitoring to check if the particular area is safe for the humans to jump to do a scuba diving. It can also be used for obstacle detection and alerting it, which may be used for detecting huge ice berg, rocks or any substance that can collide and cause damage. This provides precaution and helps saving lives and resources by being lost.

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