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Mechatronics and Motionability of an Underwater Robot: A Review

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***Abstract*: This paper is related to the evolution of the aquatic robots with their morphology and functional attributes in unstructured habitats. The deployed system construction of such robots with different stuffs that advanced the robots from substantial to micro magnitude in underwater environments is reported. Furthermore, different automations that allow the robots with distinct body dimensions, performance, mechatronics to meet definite tasks is discussed.**

***Keywords*: Mechatronics, motion ability, aquatic robots**

1. Introduction

Marine environments are greatly subjected to harmful threats in aquatic systems such as harmful chemical leakages, disposal of unwanted materials, etc. Also, any kind of disturbances like obstacles coming in the way leads to uncertainty in the path. This arise a need to find the location of the disturbances with sustained operation & sensing under the presence of communication compulsions. This addresses a mechanism that incorporates determining the existence of source in the water. The prototype & mind of various aquatic models have evolved to attain control desires beyond the aptitude of present aquatic machines. Many robotic developers tend to deploy underwater manned robotic systems, termed robotic fish. This robotic fish could find applications in various environments such as marine and military finding deep sea fish activities, oil pipe leakage, sea bed investigation, mine retaliatory evaluate, judgment, edification of robots. This paper has overview of the mechanical design characteristics of robots that make the systems to achieve an elevated level of versatility without resulting in high intricacy and the motion ability of robots to achieve district kind of applications. Design embraces issues such as analysis, passive mechanical attributes, actuator election and deployment. Motion ability embraces velocity control, position control and immerses control. In robotic fish, the up-down movement is performed through pectoral fins. It is required to understand context and goals as a very first step. A robot that performs fast maneuvers is different from those that swim efficiently for long distances. Many of them face challenges during station keeping under large disruption, fast maneuvering, power-efficient continuance swimming, route planning and tracking. Section II reviews the design issues considerations of different underwater system prototypes.

2. Considerations for the Design of Underwater Machines

Varieties of mini actuator such as a polymer actuator, a piezoelectric actuator, a shape memory alloy actuator, an electrostatic actuator, a giant magnetostrictive actuator (GMA), an optical actuator have been actively investigated for their potential applications to mini machine technologies. Because of the advances of the precise process technology, and further progress in this field, many micro robots have been developed for many purposes. Benefit of this fact is that it can work in a very small area. Different types of fish-like micro robot employing GMA actuator, polymer actuator, shape memory alloy (SMA) actuator, piezoelectric (PZT) actuator have been concerned. However, there are some weaknesses such as concise structure, low outcome, discharging electric current, safety in water, and so on. An ionic conducting polymer film (ICPF) actuator that produces biomimetic fish-like propulsion for an aquatic mini robot swimming structure in water or aqueous environment is developed. The ICPF actuator is made from the film of perfluorosulfonic acid polymer (Nafion 117, du Pont and company) chemically plated on both its sides with platinum [20]. Due to the fast response, driven by low voltage (about 1.5 V) in wet conditions without electrolysis, safety in body, and so on, the ICPF actuator is beneficial to usual polymer gel actuator. For this, an ionic conducting polymer film (ICPF) actuator that incorporates a new prototype model of an aquatic fish-like micro robot as the servo actuator to acquire swimming motion with three degrees of freedom is developed. This micro fish like robot has prototype that is 10 mm in width, 45 mm in length, 4 mm in thickness. It has a body posture adjuster, two tails with a fin driven respectively and a buoyancy adjuster. By altering the frequency of input charge between 0.1 to 5 Hz in aquatic and the magnitude input charge between 0.5 to 10 V, the moving parameter of the underwater micro robot is measured. The wood material made the micro robot to like a fish a) the ICPF actuator drives a pair of tail, b) for providing a electric current to the ICPF actuator, the load wires, c) to produce a high propulsive force, a couple of fins are installed in parallel combination. No force is required to drive the fins. The same ICPF actuator allows buying the buoyancy adjuster that is below the micro robot. The body of micro robot is mainly made of wood material for lightweight. In to verify the mechanism of the micro robot, the swimming experiments in water by changing the voltage frequency is carried out [27]. The research explains: 1) The body work of the micro robot is efficient, 2) By varying the frequency of the input voltage, the swimming velocity can be operated, 3) the movement of the micro robot in different directions i.e. left motion, right motion, forward can be achieved by varying frequency namely f1 and f2 and the magnitude of the electric potential, 4) the vertical motion of the micro robot and the arise speed can be supervised by varying the frequency and magnitude of the input voltage on the buoyancy adjuster [22]. A PZT (Pb(Zr,Ti)03) as an actuator can be utilized to build a micro robot that requires the effects of the resonance condition and a magnification mechanism to enlarge the displacement of the PZT to some extent [26], [28], [29] and [30].

Using an oscillating foil that acts as a propeller and a flexible posterior body, a four-link biomimetic robotic fish that is a radio-controlled is developed. The swimming velocity of the robotic fish is modified by regulating joint's swinging frequency and its alignment is adjusted by different joint's diversions. A robotic fish with a structure like a real fish underwater vehicle that is based on the immersing skills and the structure of a fish: basically the vibrating body movement, the highly manageable fins and the high facet ratio lunate tail is outlined [19]. This robotic fish basically comprises of control sector (onboard microprocessor and peripherals), transmission unit (wireless receiver), base (head, aluminum exoskeleton, fore body), activate unit (4 dc servo meters), accessories (tail, battery, fin, waterproofed material), etc. Most of the micro robot varies in their material structure. This includes a small miniature aquatic vehicle on which due to a flexible fin, the vehicle propels itself through oscillations that is mounted in the stern. By two curved-beam bending piezoelectric actuators, the fin is driven through a mechanism. For rigid body guidance and optimization routine is used to design the mechanism. The Bernoulli Euler method is used to model the actuators. By employing modal analysis and applying Hamilton's principle to the actuators resulted in a dynamic actuator and compared to experimental data. This vehicle possesses caudal fin motions that are governed by sensor (THUNDER) curved-beam piezoelectric actuators and by two Thin-layer composite Uni morph ferroelectric Driver. The goal for employing piezoelectric actuators in the task is that when subjected to a sinusoidal voltage the linear oscillatory motion they possess is the analog of the motion a caudal fin possess during thrust generation [21].

In order to operate robotic fish in a varying environment, navigation capability is required. A 3D simulator is used for autonomous navigation and control of motion. By using certain object models like sonar sensors, water, swimming pool, obstacles. This aimed to certain work such as by understanding the relationship between motion control parameters of the joints and robotic fish locomotion to simulate the hydrodynamic model of a robotic fish. To mimic the real fish behaviors like constant swim, decelerating/accelerating swim, hover and turning, to develop fish-like MCAs for the robotic fish. Also, to pursue a moving target, to avoid obstacle, to swim in an appointed trajectory, the ANA in the robotic fish is tested. [18]. A free-swimming biomimetic robot fish is based on an improved kinematic propulsive model. By the fish's both kinematic parameters and morphological parameters, the performance of the robot fish is determined. According to ichthyologic assumptions of propulsion, a configuration taking into consideration of both possibility of control methods and mechatronic restrictions in physical accomplishment is presented, where many joined robotic fish propelled by a adjustable posterior body and an swaying tail fin can be easily originated [16]. By hybrid systems theory, a hierarchical structure for control of autonomous robots is proposed which describe systems governed by a discrete set of continuous modes of operation and transitions between these modes [25]. Some of the water robots are self-configure based on modular optical. It provides certain goals: tiny, modular and ascendable architecture, capability to navigate and find other robots, ability to transmit with other modules, leading as a data mule is an aquatic sensor habitat, ability to land with other modules at certain places in the environment [15].

A tiny submarine [17] has been suggested as a sensor is such a habitat. The robot holds a mote sensor and can adjust its own depth. Some gliders like sea glider [23] are modified to go to a programmed insight and come out while having measurements, going for thousands of kilometers in a saw tooth structure. Most of the work has been in the area of Autonomous Underwater Vehicles (AUVs), their motion and navigation, aquatic communication, holding and sensors [24]. The mechanical structure of robotic fish in some tasks is made such that it can operate in 3D environment based on observations of fish swim behaviors. The robotic fish [4] is provided with a three or four degree of freedom (DOF) tail, and is handled by 4 onboard computers (3 PICs and a strong Gumstix Linux PC) and over 10 embedded sensors. Fin actuated water vehicles [11] that utilize geometric methods for modeling and control of swimming in water. It moves and maneuvers utilizing a tail that is two links actuated and separately actuated pectoral fin bow planes. Some AQUA robots depend on vision based observing to work within its environment. Because of the inherent physical characteristics of the aquatic environment, vision systems for underwater robots must act with geometrical disformation: aggressive lightning conditions, color and excluded particles called as water snow [12]. These can have certain features that helped to perform some tasks. An aquatic cleaner robot [13] recalls solid things that are seeked on the surface area of water. The cleaner robot named "Kraken" is made up of five modules: optoelectronic identification, recollection, propulsion and stake systems.

However, fish locomotion is the vital task that could be performed efficiently. For this, some robotic fishes have intended to the development of the caudal fin and self-propelling pectoral robotic systems. Information from bio robotic fins is provided in terms of the usefulness of using robotic systems for grasping fish movement dynamics. Due to the robotic fins, it was proven that fine changes to the mechanical characteristics and kinematics of fin rays can influence significantly the amplitude, direction and time course of 3d forces used in maneuvers and propulsion [9]. Also, by utilizing the inherent sensing ability of ionic polymer metal composition (IPMCs), a novel bio superlated artificial lateral line system is used for aquatic systems [5]. Bodywork with body length (BL) of 8 cm, consisting of 5-millimeter scale IPMC sensors was constructed. In specific, the system accounts for vital hydrodynamic effects, such as damping and added mass, along with it oscillate and yaw motions because of vibrations of the tail for free movements [8]. An elastic pulsed jet thruster for soft unmanned aquatic vehicles [2] which takes inspiration from cephalopods both for the swimming way and morphology is proposed. By collapsing periodically an external elastic shell the robot swims and then refills it with ambient water. The expansion of the chamber occurs on its because of the forces created within its thickness due to the strain created during the contraction and the cables caused actuation to the contraction of the chamber radially pulled by a geannotor. By reaction, the collapse of the shell speeds up fluid across a nozzle that causes thrust. Another kind of the body shape also reflects underwater propulsion. The multiple arms structure of octopus dedicated robotic systems allow the creation of flexible tools for aquatic applications [3]. Detailed computational fluid dynamic analysis supports the system that includes fluid drag contributions. Explorations are currently under way to create dexterous robotic system arms inspired by the mechanical characteristics and bodywork of the octopus arms [10], [4].

In [1] different kinds of soft robots that duplicate the capability of cephalopods to move in the aquatic habitat by means of pulsed jet propulsion is discussed. In this view, the robot is the initial one of its type in that it concatenates the concepts of a soft robotics with the theories of vortex enhanced pulsed jet propulsion. A growing fascination for bio inspired technologies has lead, in addition to standard UUVs, to the creation of a number of underwater robots which exhibit alternative approach for the locomotion [7], [6].

3. Conclusion

The paper overviews the advancement of multitude sorts of watery robots which are constructed with diverse physicalness. The vital factor in the design process hence exists in the precise dimensioning of the configuration. This permits the robots to sustain extensive tension thus allowing them worthy for an entire modern scope of applications. Furthermore, the emerging concept of aquatic robotic mechanism will be incorporated in a number of areas, from planetary exploration, to micro and nano manufacturing, to cooperative control of unmanned aerial vehicles (UAVs). Gas leakage source using distributed sequentioning could be found in aquatic environments.

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