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Underwater e-Fish Autonomous Robot

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Abstract: *Exploration and simulation interfaced with automation is the need of the day in the sphere of intra-vehicular communication. Built on the conception and perception pertaining to internet of things, cloud computing and acoustic sensor networks, our perspective deals with the development of 'Underwater e-fish autonomous robot' with embedded background and interlink it to the simulation process. The significant feature of this vehicle is its self-charging power generation method. The main problem concerned with existing underwater robots and vehicles is the power required to drive the vehicle. To overcome this, we suggest the use of piezo-electric transducers and a thick rubber film cohesively connected by means of a valve and tube. The principle of difference in pressure levels in oceans and seas can be made use of in this technique. On automatic operation, the proposed servo mechanism offers strong electromechanical coupling and large dynamic stresses in bending actuation as well as actuation capability over a range of frequencies for adaptive swimming. The vehicle can be developed for multi-purpose designations based on the application domain under the notion of acoustic sensor networks.*

Keywords*:* e-Fish, Piezo-electric, Robot.

INTRODUCTION

The structure of the 'Underwater e-fish autonomous robot' can be described as an autonomous soft-bodied robot that is both self-contained and capable of rapid, continual body motion. The detailed design, modelling, fabrication, and control of the soft fish focus on enabling the robot to perform rapid escape responses. The robot employs a compliant body with embedded actuators emulating the slender anatomical form of a fish. In addition, the robot has a novel fluidic actuation system that drives body motion and has all the subsystems of a traditional robot on board: power, actuation, processing, and control. At the core of the fish's soft body is an array of fluidic elastomeric actuators. The fish is designed to emulate escape responses in addition to forward swimming because such maneuvers require rapid body accelerations and continuum-body motion. These maneuvers showcase the performance capabilities of this self-contained robot. The kinematics and controllability of the robot during simulated escape response maneuvers are analysed and compared with studies on biological fish. During escape responses, the soft-bodied robot has similar input–output relationships to those observed in biological fish. The major implication of this work is that robots can be both self-contained and capable of rapid body motion. This type of design offers strong electromechanical coupling and large dynamic stresses in bending actuation as well as actuation capability over a range of frequencies for adaptive swimming.

Servo mechanism

The movement of vehicle corresponds to hydraulic technology. By circulation of water through internal body channels with the Futaba servo being attached to the fins, dynamic movement and diving capabilities can be introduced. These innovations enable prolonged fish-like locomotion in three dimensions. The servomotors are controlled by a personal computer with a R/C transmitter and a D/A converter. A control program on the personal computer realizes various motion pattern. This green power, eco-friendly technique can be used to fuel the vehicle in any desired deep sea exploration similar to that of a fish movement and hence, the name e-fish

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autonomous vehicle.

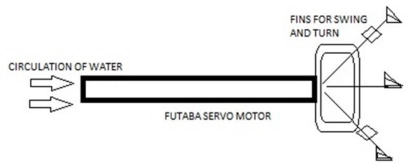

Figure 1. Servo mechanism

The autonomous e-fish initially swims straight, and gets kinetic energy. Next, the tail turns to one side, and keeps the posture to the side. This turns by hydrodynamics force. Though real fish turn skillfully using not only tail fin but also pectoral fins or ventral fins, we sketched a structure of the prototype, which turns with only swing of tail fin. As the tail fin is utilized both propulsion and turning, the underwater.

Charging technique

On a statistical analysis, the robots under water last for around six to eight hours and the manual operation of the bots add on to the issues relating to underwater automation. To go by, the significant feature of the 'Underwater e-fish autonomous robot' is its self-charging power generation method.

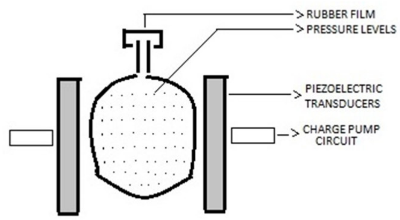

Figure 2. Piezo charging technique - cross sectional view

In this technique, we suggest the use of piezo-electric transducers and a thick rubber film cohesively connected by means of a valve and tube. The principle of difference in pressure levels in oceans and seas can be made use of in this technique. As the pressure changes continuously, the contraction and expansion of rubber film due to difference in pressure makes the related interactions between the piezo-electric transducers. As a result of the intermediate vibrations produced, these could be tapped and used in the circuit consisting of transistors, charge pump storage circuit using CD4093, Schmitt trigger ICs, Schottky diodes, Simple link Wi-Fi interfaced with Tiva TM4C123GH6PM microcontroller. With the knowledge of interfacing of microcontroller with LCD, ADC, control of transistors (as switch), a simple charge pump storage circuit using CD4093 Schmitt trigger IC for interlocking the P-Mosfets switches and programming the Tiva TM4C123GH6PM microcontroller for monitoring and control can be designed.

SENSOR DATA ACQUISITION

To realize underwater applications, many design principles and tools from ongoing, ground-based sensor net research can be made use of. Considering some of the challenges which are fundamentally different, the sensor data acquisition in underwater networks can be established First, radio is not suitable for underwater usage because of extremely limited propagation. While acoustic telemetry is a promising form of underwater communication, off-the-shelf acoustic modems are not suitable for underwater sensor-nets with hundreds of nodes: their power draws, ranges, and price points are all designed for sparse, long-range, expensive systems rather than small, dense, and cheap sensor-nets. Second, the shift from RF to acoustics changes the physics of communication from the speed of light to the speed of sound which offers a difference of order of five in magnitude. While propagation delay is negligible for short-range RF, it is a central fact of underwater wireless. This has profound implications on localization and time synchronization. Finally, energy conservation of underwater sensor-nets will be different than on-ground because the sensors will be larger, and because some important applications require large amounts of data. We are therefore investigating three areas: hardware, acoustic communication with sensor nodes, protocols, underwater network self-configuration, MAC protocol design, time synchronization, and localization and mostly off operation, energy-aware data caching and forwarding.

The Acoustic model refers to the communication with the sound waves. In underwater environment, communicating medium can be either radio, optical or sound (acoustic) waves. But the non-acoustic waves are electromagnetic waves which suffer from high propagation losses as well as scattering problems. These non-acoustic waves do not travel long distances in underwater environment. Radio waves require high transmission power as well as long antennas to communicate and Optical waves suffer from high signal attenuation so it can travel short ranges only. Hence sound is the best communicating medium for underwater networks. Till now and in near future also, the acoustic waves can be seen as the best communication medium for wireless networks.

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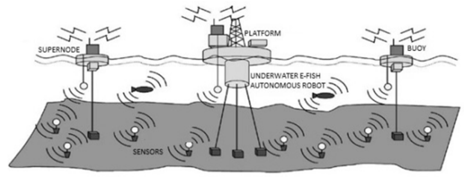

Figure 3. Underwater acoustic sensor network

In the solution put forth in sensor data acquisition, the sensor nodes are present beneath the water level as well as floating on the surface of the water. Under water, nodes are communicating via the acoustic communication and above the surface of water, the nodes are communicating via the radio signals. There can be a master data collector center or an analysis center which can collect the information from these nodes for various purposes. Our perspective is to observe four different types of nodes in the system. At the lowest layer, the large number of sensor nodes is deployed on the sea bed. They collect data through attached sensors and communicate with other nodes through short-range acoustic modems. Several deployment strategies of these nodes are possible; here they are anchored to the sea bed. Tethers ensure that nodes are positioned roughly where expected and allow optimization of placement for good sensor and communications coverage. Node movement is still possible due to anchor drift or disturbance from external effects. Nodes will be able to determine their locations through distributed localization algorithms. At the top layer are one or more control nodes with connections to the Internet. These control nodes may be positioned on an off-shore platform with power, or they may be on-shore; we expect these nodes to have a large storage capacity to buffer data, and access to ample electrical power. Control nodes will communicate with sensor nodes directly, by connecting to an underwater acoustic modem with wires. In large networks, a third type of nodes, called super-nodes, can be deployed. Super-nodes have access to high speed networks, and can relay data to the base station very efficiently. We are considering two possible implementations: the first involves attaching regular nodes to tethered buoys that are equipped with high-speed radio communications to the base station. An alternative implementation would place these nodes on the sea bed and connect them to the base station with fiber optic cables. Super-nodes allow a much richer network connectivity, creating multiple data collection points for the underwater acoustic network.

APPLICATIONS

The vehicle can be developed for multi-purpose designations based on the application domain it is used with. It is built mainly from the Intel, Texas Instruments microcontrollers and ARM products. The most innovative aspect of this vehicle is sought by deploying it to detect the black boxes during airplane crashes. The issue pertaining to the detection of black box or underwater beacon locator is the power supply required to fuel the robotic vehicle for long hours under water and the range it is attributed to. Since, this underwater e-fish autonomous vehicle is driven by a self-charging pump circuit, it can obviously be used for this purpose. The Sentinel XF SONAR is used in this vehicle for detecting the black box and its functionality is empowered with the SONAR acoustic nodes deployed over the surface of water and this acoustic ranging is controlled by means of protocols defined by TDMA and CDMA. The same acoustic ranging node method can be used to resolve the Indian fishermen issue by deploying the autonomous vehicle in the border waters of India and Sri Lanka with alert system application developed for it. Another component is the LMP91050, a programmable integrated sensor used for gas detection in the event of leakages from ships and the radioactive emissions from nuclear plants. Also, the water resistant sick sensors can be used for this purpose. Moreover, for high-resolution sensing of targets like submarines, the LDC1000 inductive sensor along with the SONAR technique is incorporated in this vehicle. The fabricated TMP75B temperature sensor, salinity sensor and the PGA400-Q1 pressure sensor are also embedded to study the nature of underwater flora and fauna. Since the application of GSM modules under water are not well served for many purposes, an acoustic sensor network can be established to monitor the performance of underwater e-fish autonomous vehicle. Once underwater equipment are connected with acoustic sensor networks, it becomes an easy task to remotely control and operate some equipment. The primary differences between modulation techniques lies in the complexity of the receiver, the bandwidth required, and the minimum acceptable received signal-to-noise ratio (SNR). In the acoustic sensor network, all these features are well defined and inter-linked for underwater purposes.

EXPERIMENTAL RESULTS

As a part of the sample working model, a mini autonomous vehicle of length 1.3 meter, weighing approximately 2.6 kg, driven by Futaba S148 with power supply of around 15-20 V can be set up with a cost effective budget of INR 8000. This model can be put into operation with some of the mentioned features integrated into it and introduced underwater along the Indian-Sri Lankan borders to test the working of the same. From the perception of a developer of the 'Underwater e-fish autonomous robot', a prototype to illustrate the practical implementation can be experimentally ascertained. As an paradigm, our team has developed a underwater robot connected by means of Intel Edison with a hybrid application to control the movement so as to observe the various special cases in a real time environment. In the hybrid development spheres, the Ionic framework is used with the capability of linking it to IOT based cloud services.

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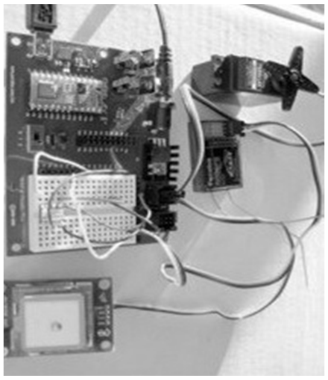

Figure 4.a. Experimental setup

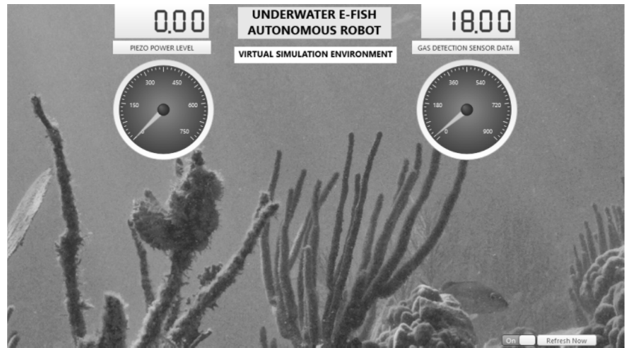

Figure 4.b. ThingWorx virtual simulation environment

On a better and dependable means of using cloud based IOT services, ThingWorx cloud platform is greatly made use of to facilitate the sensor data acquisition. The ThingWorx Composer 5 is utilized taking into account of the quick streaming of driving data in this platform. To bind the values of sensor from nodes, the corresponding application key of the server used in the Arduino IDE code and is then compiled, uploaded into the Intel Edison. In the Figure 4.b, the virtual simulation environment is shown along with the sensor data display widgets. For the data visualization, the wide range of widgets in the composer are used to display the data in mash-up along with e-mail alerts for specific purpose that are used to serve the warning notes by analogously comparing the data obtained through sensors deployed at the particular nodes.

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