ROV-based acquisition system for water quality measuring

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***Abstract* — this paper presents the design and implementation of a ROV-based acquisition system designed for water quality monitoring through the acquisition of oceanographic parameters of Peruvian water resources such as rivers, lakes and oceans. The robotic platform integrates a video camera, a multi-parameter probe for water quality analysis and an array of three hydrophones in order to measure underwater noise. The versatility of an underwater vehicle is exploited by centralizing data acquisition and logging in a sole flexible platform. The presented prototype is developed to be used as a research platform and as a measurement tool for the Peruvian Institute of the Sea (IMARPE—Instituto del Mar del Perú) in order to extend its capabilities on oceanographic parameters monitoring. Preliminary results of the ROV hydrophones and multi-parameter probe are presented and discussed in this work.**

Index Terms – water quality; underwater pollution; ROV; underwater noise

I. INTRODUCTION

Underwater vehicles and robots such as ROVs (Remotely Operated Vehicles), AUVs (Autonomous Underwater Vehicles) and gliders have become popular robotic platforms in oceanographic and environmental analysis due to its capabilities of performing long-term operations, acquiring geo-referenced data and navigation maneuverability. These surveys will allow the evaluation of the environmental status of marine areas which are difficult to access for humans. Water pollution such as in rivers, lakes and oceans are generated by anthropogenic and industrial activities through solid, chemical waste and underwater noise. Common underwater sensors to evaluate this scenarios includes imaging sensors, multi-parameter probes and acoustic sensors [1]. Imaging sensors such as cameras and side scan sonars are used for visual inspections and mapping. Underwater probes contain a series of sensors for measuring physical and chemical properties to evaluate the quality of the environment in terms of pollutants and conditions for marine life sustainability. Finally, hydrophones measure underwater noise such as the generated for machinery, explosives and the use of air-guns in seismic inspections that affects mostly marine mammals [2].

Underwater video is almost inherent in ROVs since it is used for inspection operations, such as visualization of the surroundings, fishing activities, discover of solid wastes, and others. Chemical and physical parameters are usually measured by underwater CTD (Conductivity – Temperature – Depth profiler) probes in oceanographic surveys. Additional parameters such as dissolved oxygen, important for determine living conditions for microorganisms and pH for ocean acidification problems [3] are also measured by probes. Other specifics analyses are performed in laboratory through the collection of water samples. Underwater noise is measured deploying sets or arrays of hydrophones connected to an amplifier and a data logger from a vessel. Intensity in time and spectral characteristics are used to determine acoustic signals in order to model certain phenomena. Localization of the source can be obtain by triangulation [4].

Therefore, we present the design and implementation of a ROV for water quality measurement that integrates three measurements: visual imaging, through a video camera; water quality parameters, through a configurable six channel multi-parameter probe and underwater noise, through a set of three hydrophones. The ROV is intended to be a research platform and a measurement tool for the Peruvian Institute of the Sea (IMARPE—*Instituto del Mar del Perú*). It is custom designed for this application in order to be easily deployed by two people without a complex launch and recovery system.

This paper is organized as follows. In Section II water quality parameters and how are they measured are described. In Section III an overview of the design and implementation is presented. In Section IV, test setups of the integrated system is presented. In section V the conclusion and future work are discussed.

II. UNDERWATER INSTRUMENTATION

Technological innovations in sensors drive together with the methods for deploying them into water. Different marine observation methods are applied nowadays, depending on the task, instruments can be driven by divers, anchored to the seabed, anchored to a buoy, towed by a ship and mounted on underwater robots.

Within underwater robots, ROVs are connected through a tether to a vessel allowing a considerable bandwidth to stream large amounts of data including video and highly sampled signals in real-time. The navigation range is limited to the tether length and it is driven by an operator. AUVs are not limited in range to a tether and can perform long-term/long-distance inspections but they cannot broadcast large amounts of data while diving, consequently the data is transmitted when surfacing or logged until the end of the

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mission. A good navigation system and at least intermittent communication is important to accomplish the task given [1].

A. Submarine Video Inspection

Underwater video footage is a direct media to observe aquatic environments. Water quality aspects such as litter and debris can be logged as well as the interaction of the surrounding wild life [5]. In [6] a 22-year video annotation of anthropogenic debris at 2000m to 4000m using ROVs is presented. In [7] a fishing-environmental study, video recordings were used to document the impact of ghost fishing, term referred to lost or abandon fishing gears that continue capturing fishes and other species while travelling or when stuck in the seabed, Fig. 1 shows snapshots of the survey.

B. Oceanography Monitoring

Oceanographic monitoring is often performed with the use of CTDs deriving indirect variables such as salinity and density along others. For large areas surveys the probe is mounted in ships or gliders [8]. There are other multiple parameters that can be measured to characterize water quality such as turbidity, chlorophyll, pH, chloride, nitrate ion, oxygen dissolved, etc. applied to salt or fresh water [9]. Recent arising phenomena such as global climate change, ocean acidification and littering are reflected in oceanographic parameters [10]. For instance, air pollution due to anthropogenic emissions of CO_2 is exhibited in water resources acidification presenting decreases in pH [3].

C. Underwater Noise

Underwater noise pollution comes from ships, underwater engines, explosives and air-guns noise. Any kind of energy induced in underwater scenarios affects the environment [10]. Marine species of fishes, cetacean, turtles, and their ecosystems can be affected adversely. Air-guns can emit intense acoustic waves in seismic prospection in the search for resources in the oil and gas industry [2].

In the last years a series of events has caught public attention due to the fast growing of oil and gas industries in Peru. Environmental issues related to underwater noise in seismic prospections has been reported showing the impact of underwater blasts and machinery on marine mammals [11].

In [4] an underwater blast detector system based on a hydrophones array and the cross correlation of the signals to estimate the origin of the blast is presented. In Peru, similar systems were implemented for characterizing blasts from illegal fishery and evaluate the impact of seismic prospections on dolphins [12].

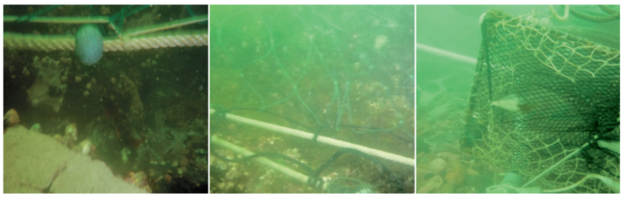

Fig. 1: Ghost fishing video footage – Ancon - Peru
Courtesy of IMARPE

III. VEHICLE OVERVIEW

The robotic platform is designed to assure its functionality in freshwater and seawater. The external body is made of HDPE (High-Density PolyEthylene) which is highly resistant against corrosion. All the electronics are contained in a water tight cylinder with underwater connectors for the devices mounted in the external body. The ROV is 0.75 (L) x 0.6 (W) x 0.55 (H) m with a weight in air of 50 Kg, it includes two handles at the top to simplify launching and recovering (Fig. 2).

The control is centralized into an embedded computer, based on a BeagleBone — general purpose Linux computer with a 720MHz ARM processor, also used as a data logger and communicates with an external computer for operation. The video stream, the probe data and the signal from the hydrophones are stored within information of the location of the ROV given by an IMU and the depth sensor from the probe. Fig. 3 shows an overview of the ROV and the hardware connection.

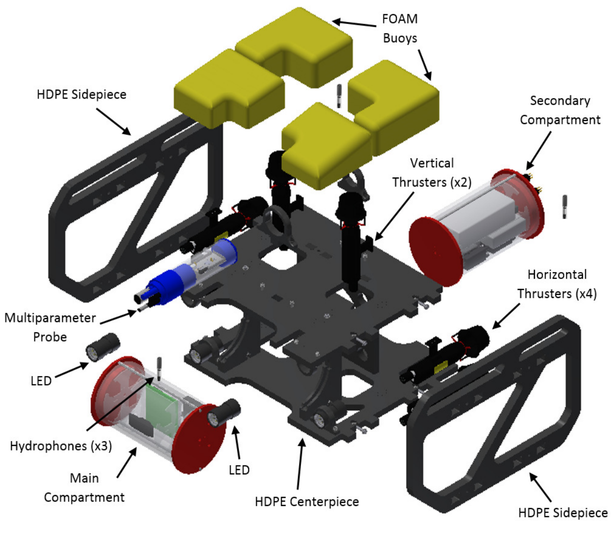

Fig. 2: ROV explode view – components

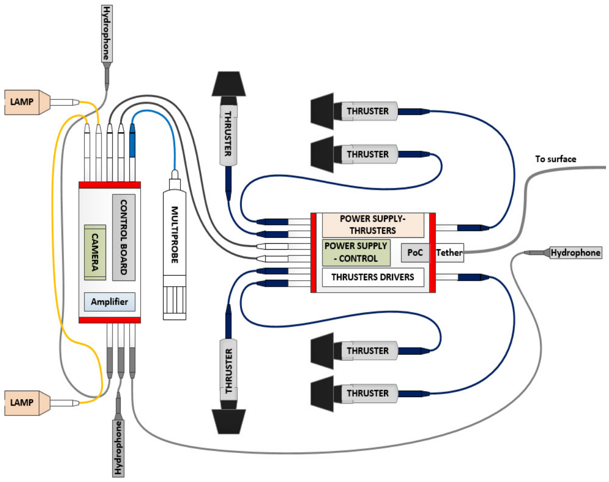

Fig. 3: Connection diagram of the ROV

A. *Video and Interface*

The video is streamed online through an Ethernet connection between the external PC and the embedded PC where a webserver is host. The interface can be loaded from a web browser, the webpage shows the streamed video along with the monitored parameters. In order to operate the ROV, a gamepad is connected to the external computer and the actions are also shown in the interface. Fig. 4 shows the main tab, the orientation is monitored through a navigation feedback panel on the left and the values on the right. The estimation of the position is also shown on the right.

B. *Multi-parameter probe*

The water quality sensors were selected according to the requirements of the IMARPE in order to include common parameters for a general overview of water conditions. In that sense the parameters for the probe are: temperature, dissolved oxygen, specific conductance, salinity, pH, depth and turbidity. The specifications of the sensors are presented in table 1.

Table 1: ROV mounted sensors overview

Item	**Specification**
Camera	Full HD resolution
Temperature	-5 to 50 ºC
Dissolved Oxygen	0 to 50 mg/l
Specific Conductance	0 to 100 mS/cm
Salinity	0 to 70 PSS
pH	0 to 14 units
Depth	0 to 100m
Turbidity	0 to 3000 NTU

Table 2: Hydrophone parameters

Item	**Specification**
Usable Frequency Range	1Hz to 170KHz
Receiving Sensitivity	-211 dB ± 3dB re 1V/uPa
Operating Depth	700 m
Custom Hydrophone Amplifier	
Adjustable gain	Up to 60 dB
Low pass filter	None, 0.1KHz or 30 KHz
High pass filter	None, 0.1Hz or 10 Hz
Digital sampling frequency per channel	Up to 1MHz

C. *Hydrophones*

The hydrophones are selected due to its bandwidth, sensitivity and frequency response. Underwater noise from engines are mostly in low frequencies but there is an option to use the robot for mammal studies such dolphins which uses higher frequencies for communication, therefore the hydrophone selected has a bandwidth from 1 to 170 KHz (table 2). The sensitivity and frequency response is acceptable compared to other laboratory hydrophones.

The output is in low powered voltage sensitive to noise, therefore it has to be conditioned (amplified and filtered). It is done by a custom made configurable conditioning board. The parameters are set by the embedded computer prior to logging. Gain can be set up to 60 dB and there are fixed filters for configuring the board: 0.1 or 10 Hz high pass filter and 100Hz or 30 KHz low pass filter.

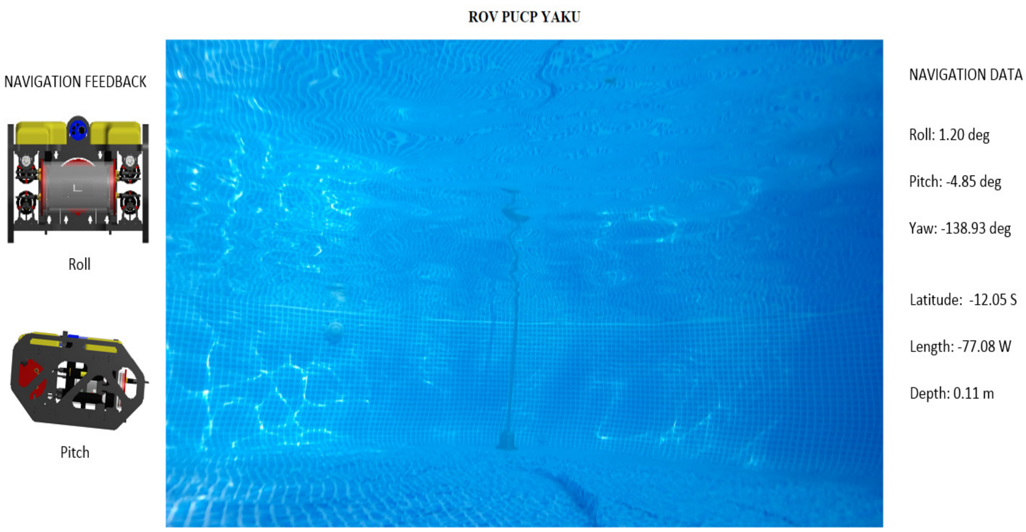

Fig. 4: ROV interface

Fig. 5: Functionality test setup

The amplifier is designed with a two amplifications steps prior to the Programmable Gain Amplifier (PGA) with a total gain of 13db to assure a signal in the order of millivolts. Figure 5 shows the block diagram of the custom hydrophone amplifier where the selectors for filters and gain are observed within the digitalization process.

D. ROV Navigation and Control

There are four thrusters mounted in horizontal position and two in vertical position, providing 5 degrees of freedom to the ROV to be used: forward/backward, up/down, yaw pitch and roll. The localization is estimated through an Attitude Heading Reference System (AHRS) which integrates an Inertial Measurement Unit (IMU) a depth sensor (from the probe) and a GPS. Technical specifications are shown in table 3.

When the robot is in the surface uses the GPS for stablishing a reference position. Once it dives underwater the GPS is neglected and the localization sensors are used for estimating the position.

IV. Experimental Setup

In the preliminary stage the ROV functionality is tested in a 3 m diameter pool and 1.5 m depth (Fig. 6). The ROV with the monitoring sensors: video, six parameter probe for water quality and three hydrophones; along the navigation sensors: GPS and IMU are tested.

The hydrophones are mounted around the ROV in a triangular position and the robot is placed in water with the thrusters turned off to avoid additional noise. The test consist in monitoring the acoustic signal of a small spherical object dropped in the pool at 1 m distance from the array. There is one hydrophone (CH1) closer to the object and the other two are symmetrical distributed behind the front hydrophone. Fig. 7 shows the result of the test sampled at 1MHz by the ROV, as expected CH1 is first stimulated followed by CH2 and CH3 which react almost synced, between 2 ms and 2.5 ms it is possible to observe a peak in all the channels with different phase which can be used to estimate the position of the noise source.

The setup for the multi-parameter probe is due to test the communication between the probe, the ROV and the online visualization of data. The probe is placed in a 6 liters container with freshwater where substances such as chlorine and bottled orange juice are added in order to alter the parameters. The results of the variations are shown in Fig. 7. The normal conditions of fresh water and clorine are logged for the first 20 seconds. Clear water have a turbidity of 0, temperature of 20ºC and neutral pH. Then 300ml of cold orange juice is added in time 21, as expected the transition is clearly notable with a regular drop in acidity (from 7.58 units to 4.55 units), a high rise in turbidity (from 0 NTU to 70.9 NTU), a small decrease in dissolved oxygen (from 104.6% to 101.7% of saturation) and a small increase of salinity (from 0.17PSS to 0.26PSS). For the navigation test, only the communication between the IMU and GPS with the ROV is tested. Further processing is needed to reduce the accumulative error from the IMU to improve the accuracy of the estimation of the position of the ROV.

Table 3: IMU Specifications

Item	Specification
Accelerometer range	±5g standard
Gyroscope range	±300°/sec
Static Accuracy	±0.5° pitch, roll
Dynamic Accuracy	±2.0° pitch, roll
Repetitibility	0.2°
Resolution	<0.1°
Sampling rate	Up to 1000 Hz

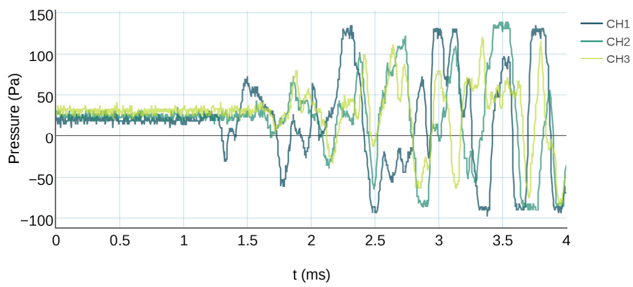

Fig. 7: Hydrophone array test

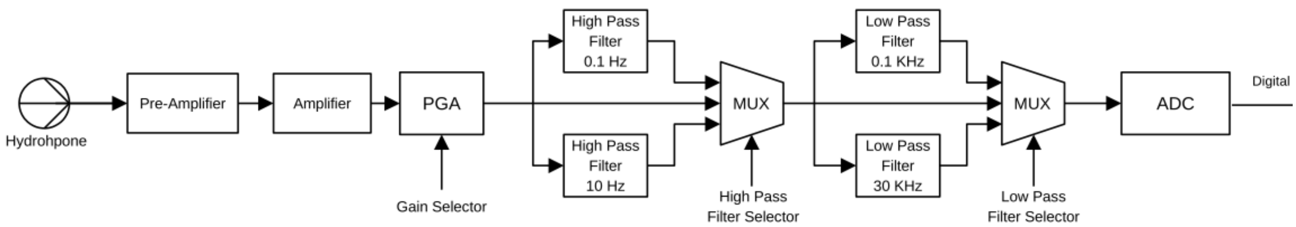

Fig. 6: Hydrophone amplifier: block diagram

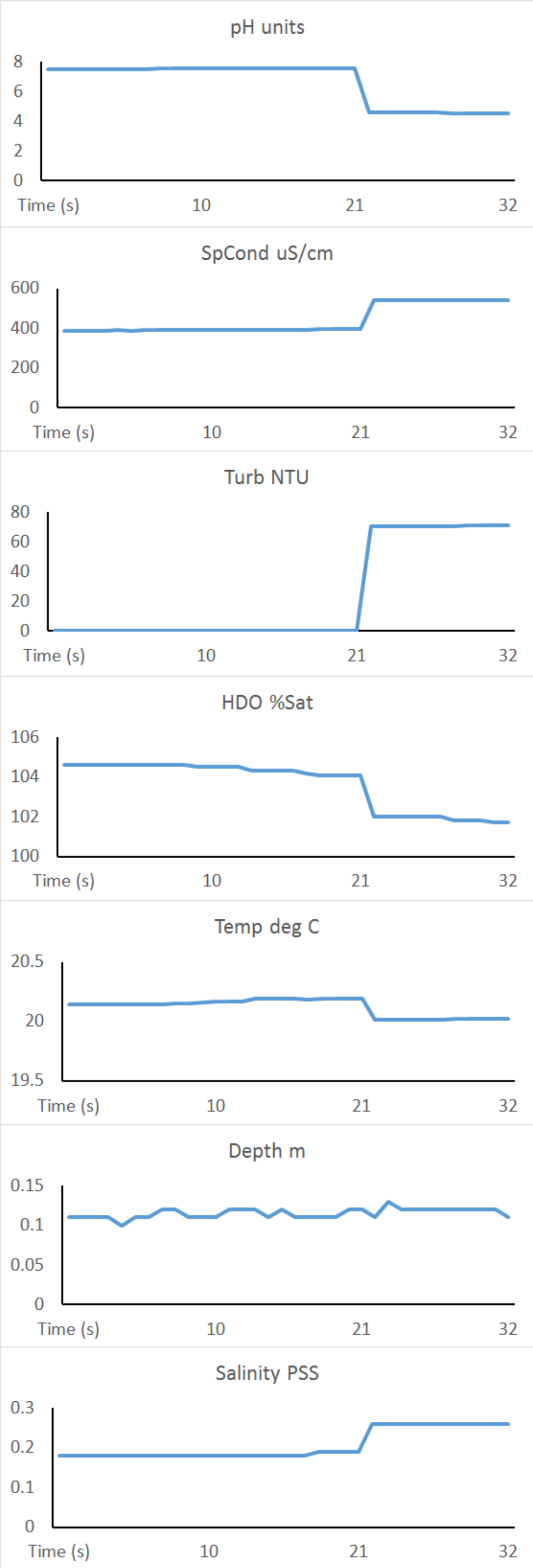

Fig. 8: Multi-parameter probe test

V. Summary and Future Work

We have presented the development of a ROV-based acquisition system for the IMARPE for gathering video, six water quality parameters and three channels of underwater noise along with some hardware basics for position estimation. The functionality of the ROV is tested making it ready for field tests.

The goal of our future work is to test the ROV in natural underwater scenarios and validate the results with the IMARPE to be used as a tool for their surveys.

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