Vilanova sea trials of Guanay II AUV

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Abstract- *This work presents the last trials of Guanay II AUV in the Mediterranean Sea. Guanay II is an AUV designed to navigate on the surface of the sea following a path and at some points it carries out a vertical dive to take measurements of a water column. During the last year we have focused on the design of an automatic control and its algorithms. For the control system, we split the controller into two loops: an inner loop and an outer loop. The first loop is responsible for setting the yaw ψ and the forward velocity u, given a reference (ψref, uref). At this level we develop a fuzzy controller which integrates the different linear controllers adjusted for different forward velocities. The second loop is responsible for setting the reference for yaw and forward velocity for a given path.*

The mission consisted of following 13 waypoints along a total journey of 3600m with three vertical dives up to 5m of deep. Through this test the operability of the vehicle was validated and different designed controllers were also tested. During this mission, a set of measurements of salinity and temperature were obtained.

Keywords – AUV, control, sea trials, Guanay III

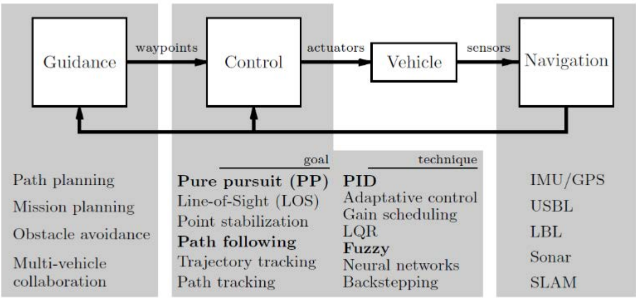

Figure 1 Guidance, Navigation and Control, and the main associated research lines

I. Introduction

Guanay II [1] is an AUV designed by SARTI Research Group from UPC. This project has gone through several processes of evolution in recent years. During the last year, we have focused on finishing the design of an automatic control and its algorithms. This work allows us to execute complete autonomous missions with the vehicle.

Guanay II must be capable of an autonomous navigation. After defining and scheduling a path, the vehicle must be able to follow it without human intervention and to cope with any environmental perturbations present in the sea. Guanay II was designed to navigate on the surface of the sea following a path and at some waypoints the vehicle can make a dive to take measurements of the water column. Works of Fossen [2] and Antonelli et al. [3] present the concept of Guidance, Navigation and Control system (GNC) which is the set of programs responsible for carrying out a mission. As the name says, it is divided into three main layers or subsystems (see figure 1). The Guidance system is the high level control of the vehicle during the mission which defines the path and the goals. The Navigation system receives the sensor data and computes the actual position, velocity and acceleration. Finally, the Control system processes the information given for both guidance and navigation systems and generates the appropriate commands for the actuators with the main objective to reduce the difference between the actual and desired trajectories.

Most of the works about the state of the art [4] design the controllers referencing the hydrodynamic model of the vehicle when it travels at a specific forward velocity in order to simplify the control design. This is right if the vehicle navigates in open sea, however, if it navigates near the coast or in the interior of sea ports, the variation of the forward velocity becomes relevant. To solve this problem, it is important to have the capability to change the working point of the controller in order to adjust the paths to these environments and keep a uniform performance through several environments. Some techniques can be found in the literature which solve this problem. For example, in [5] they use Lyapunov functions and in [6] Silvestre and Pascoal use a gain scheduling controller. With these works we develop a new methodology using a fuzzy controller as an interpolator between different controllers adjusted by different forward velocities [12].

For the control system, we split the controller into two loops: an inner loop and an outer loop. The first loop is responsible for setting the yaw ψ and the forward velocity u, given a reference (ψref, uref). At this level, we develop the fuzzy controller mentioned above. The second loop is responsible for setting the reference for yaw and forward velocity for a given path.

In this paper, we present the results of the open sea trials carried out for the AUV Guanay II in the Mediterranean Sea of Vilanova last year where we were able to test and validate the vehicle and observe its performance first full mission.

The paper is organized as follows: in Section II we specify the purpose of the test. In Section III we present the results. Finally, we present our conclusions in Section IV.

II. Purpose of the Test

The main purpose of the mission in open sea was to test all the systems designed in a real environment and validate them. First, a mathematical model for Guanay II AUV was designed. Then, a few computer simulations were carried out with different configurations and capabilities. After these, a real test in a controlled channel was performed to validate both the mathematical model and the computer simulations. So, to conclude, we needed an open sea trial to confirm the good performance of the vehicle and its main blocks, such as: the electronic system, the automatic control or communications.

- Electronic systems: The AUV Guanay II electronic systems have improved after some test fields in a swimming pool and in the sea [7] and [8]. As shown in these publications, the electronic system is composed of different parts; the batteries and their management devices; the embedded PC; some guidance and positioning systems, GPS, INS or an electronic Compass; communications; and finally the propulsion system composed of three thrusters, a buoyancy system and its control devices. All of these are shown in figure 2.

  All of these systems had been tested previously in the laboratory and in a controlled environment. However, a real test in open sea was performed to validate its performance in order to know its autonomy, maximum distance or the power generated by the thrusters.

- Automatic Control: The automatic control designed and implemented over the last years was also tested. The main blocks of this control are shown in figure 1. In the publications [9], [10] and [11] some aspects of the Guanay II control and some improvements developed for the previous platform Cormoran AUV control are presented.

- Communications: Finally, another very important system which was tested is the communication system to know its range and its performance. It is comprised of a Base Station and a Long Range Radio Frequency Communication and a Short Range WiFi Communication.

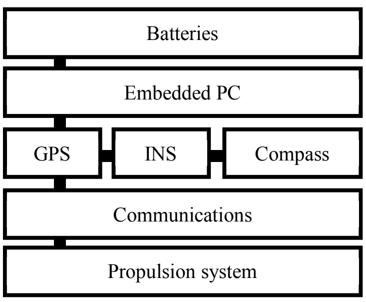

Figure 2 Composition of electronic system. Batteries, Embedded PC, GPS, INS, Compass, Communications and Propulsion system

III. Sea Trials

This final test was executed near the coast of Vilanova i la Geltrú, in the south of Barcelona close to the port. This location is very good because we can test the performance with waves and we can program a very long path for the mission.

The mission involved following 13 waypoints in a total journey of 3600m (Figure 3). The radius of acceptance is 6m, and for the inner loop we used TSK fuzzy controllers.

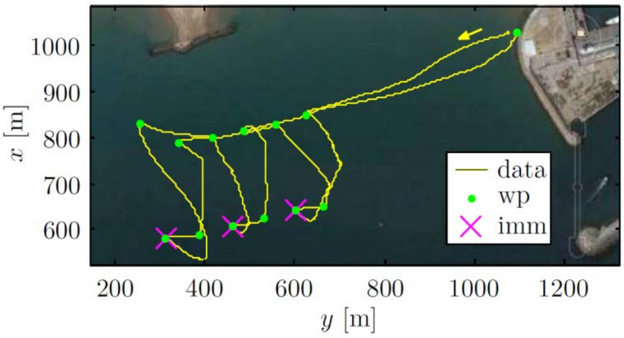

Figure 3 Final test. Navigation data where the path is the yellow line (data), green dots are the waypoints (wp) and the violet cross are the points where a dive was performed

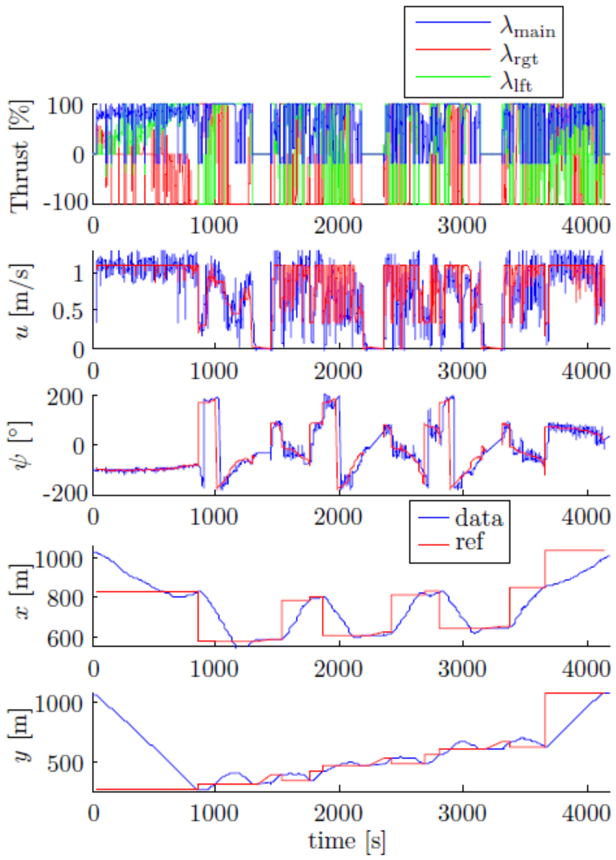

Figure 4 Final test. Telemetry data obtained during the mission. Up to down: Thrusters power, forward velocity, yaw angle, x and y position

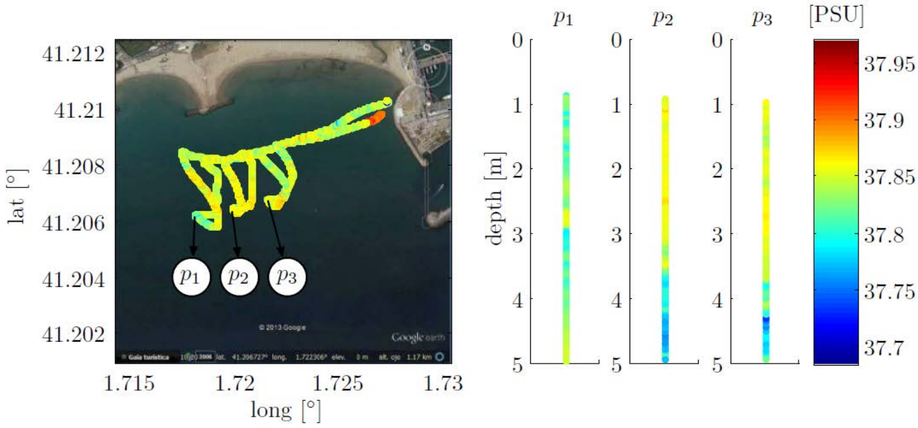

Figure 5 Final test. Salinity record

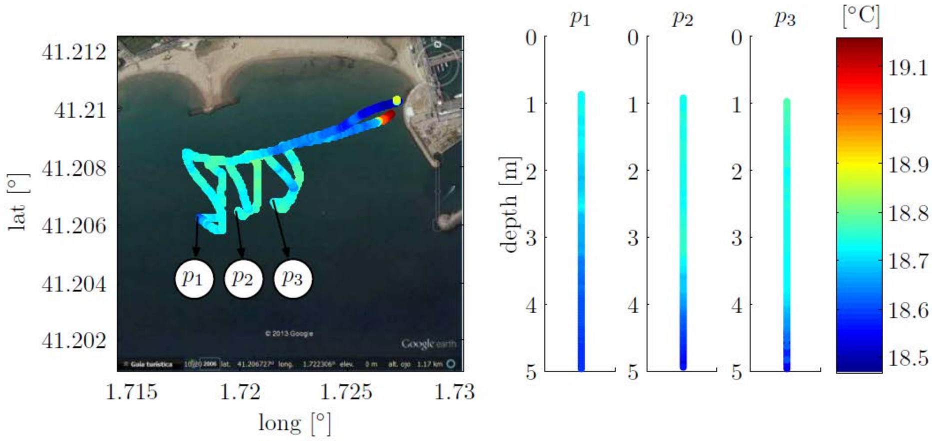

Figure 6 Final test. Temperature record

Additionally, we scheduled three vertical dives up to 5m in depth, concretely, at waypoints 2, 6, and 10. Figure 3 shows the results of this test. It took about 70 minutes to complete the path travelling at 1m/s.

In figure 4 we can see the telemetry saved in the vehicle. The first graph shows the power of the thrusters in % during the mission. The second one is the forward velocity of Guanay II. In both charts, we can observe three periods of time of about 2 minutes where the thrusters are stopped and the forward velocity is zero. In these periods of time, only the cylinder acts to a vertical immersion. Finally, the three last graphs show the angular yaw and the x-y position.

The environmental results of the test are shown in figure 5 and 6 which show the record of salinity and the temperature using the CTD. They show both the surface and underwater data at the dive points. The salinity varies from 37.68 to 37.97 PSU, and it also has variations underwater. The temperature varies from 18.47 to 19.16 ºC. It is clear that the temperature decreases when the depth is greater.

VI. CONCLUSIONS

The vehicle accomplished the mission performing all the waypoints and dives. However, the compass was a bit out of calibration, so it caused some deviations in the path. Nevertheless, all the other systems had functioned properly.

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