to increase the speed the system tends to be first order).

Conclusions

In this study was created a nonlinear model for the Cormoran vehicle with 3 degrees of freedom, this model has been linearized by taking one constant speed.
For the control action, it has a single PD controller designed for the entire system, showing that it is possible to define a target dynamic area eliminating the position error at steady state. It

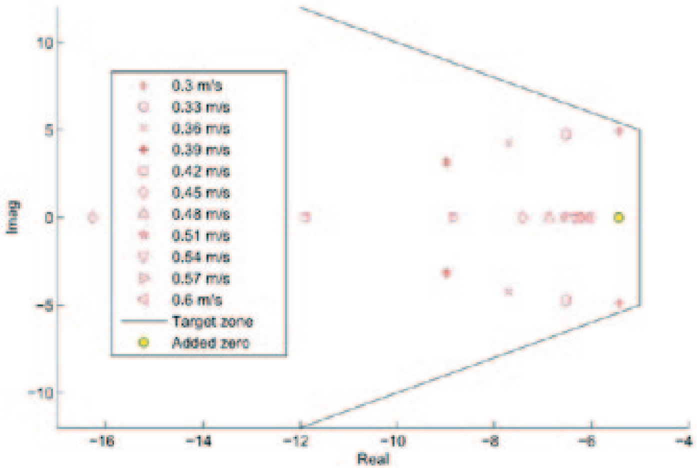

Figure 4. closed loop poles applying the PD control

also showed that when the vehicle is at higher speeds the response is even better, and therefore it is sufficient to design a single PD.

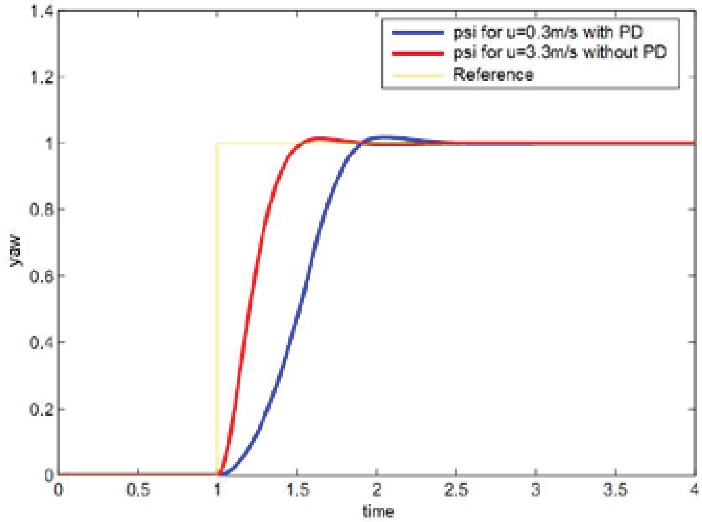

Figure 5. Responses to step input for different speeds using PD control

References

[1] D. Roig Broman, M. Martínez Ledesma, B. Garau Pujol, A. Alvarez Díaz, J. Tintoré Subirana. "A Low-Cost Autonomous Vehicles For Coastal Sea Monitoring". Mediterranean Institute of Advanced Studies (CSIC – UIB). Autumn 2005.
[2] Thor I. Fossen. "Marine Control Systems".
[3] Timothy Prestero. "Verification of a six degree of freedom simulation model for the REMUS autonomous underwater vehicle. Master's thesis, September 2001.
[4] A. Pascoal, C. Silvestre. "Depth control for the infante auv using gain-scheduled reduced order output feedback". Science Direct, pages 883-895, 2007.
[5] K. Ogata. "Ingeniería de control moderna". 3º edition.
[6] Xin-quian Bian Jia-jia Zhou Xiang-quin Cheng, Zhe-ping Yan. "Application of linearization via state feedback to heading control for autonomous underwater vehicle". IEEE International Conference on Mechatronics and Automation, 2008.

CONSIDERATIONS ON THE ELECTRONIC CONTROL SYSTEM FOR AUTONOMOUS UNDERWATER VEHICLE

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Abstract—This work proposes the development of a control system for an autonomous underwater vehicle dedicated to the observation of the oceans. The vehicle, a hybrid between Autonomous Underwater Vehicles (AUVs) and Autonomous Surface Vehicles (ASV), moves on the surface of the sea and makes vertical immersions to obtain profiles of a water column, according to a pre-established plan. The displacement of the vehicle on the surface allows the navigation through GPS and telemetry communication by radio-modem. The vehicle is 2300mm long by 320mm wide. It weighs 85kg and reaches a maximum depth of 30m. A control system based on an embedded computer is designed and developed for this vehicle that allows a vehicle's autonomous navigation. This control system has been divided into navigation, propulsion, safety and data acquisition subsystems.

Introduction

Traditionally, oceanographic vessels have been and are the most important observation platforms where multidisciplinary oceanographic studies are carried out. The high cost of using them prevents to get data with spatial and temporal resolution required. A recent alternative way, which allows ocean observations with good spatial and temporal resolution simultaneously and with lower costs are the Gliders, the Autonomous Underwater Vehicles (AUVs) and Autonomous Surface Vehicles (ASVs) [1] [2].
There is a type of hybrid vehicle in underwater observation that lies between the AUVs and ASVs, ie moving along the surface of the sea and makes vertical immersions to obtain profiles of water column. [3] [4].
The vehicle control system developed belongs to the latter group [5] [6]. It has a double hull structure where the outer hull,

Figure 1. Autonomous Underwater Vehicle used

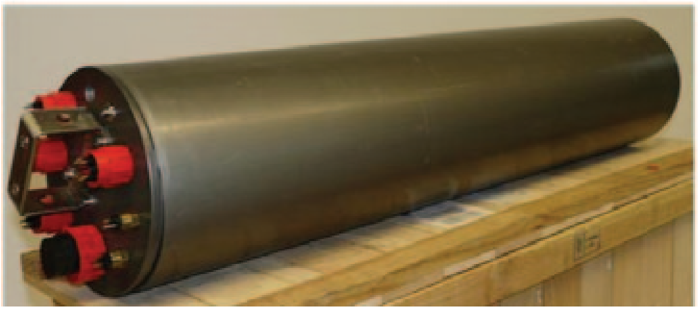

Figure 2. Interior Watertight Module.

made of fiberglass, provides a good vehicle hydrodynamic behaviour (see figure 1), but not watertight. Inside the outer case a cylindrical watertight aluminium 6063 module is attached that contains the immersion and emersion actuator, the battery pack and control system (see figure 2). The immersion actuator is a commercial pneumatic stainless steel cylinder with a displacement of 1500 cm3 and a linear electric actuator which can cover a maximum distance of 200 mm and thrust force of 3KN. Power batteries are Ni-Cd providing 21Ah, and 24V voltage [7]. In order to supply 5V and 12V voltages required for different electronic devices Mornsun dc-dc switching converters have been used.
This work is organized as follows: section II shows the control system structure and design of communication subsystems, navigation, propulsion and safety. Section III presents the experimental results obtained in the laboratory. Finally, Section IV presents the conclusions.

Control Unit
The control system is designed in a modular way with different subsystems, managed by the module control unit, which consists of a PC104 embedded computer. Figure 3 shows a block diagram of the control system. As seen, there are six modules: the control unit, the navigation system, the propulsion/immersion system, safety system, communication system and data acquisition system. The following describes each of these systems, except the data acquisition system that will be configured according to the objectives of the mission.

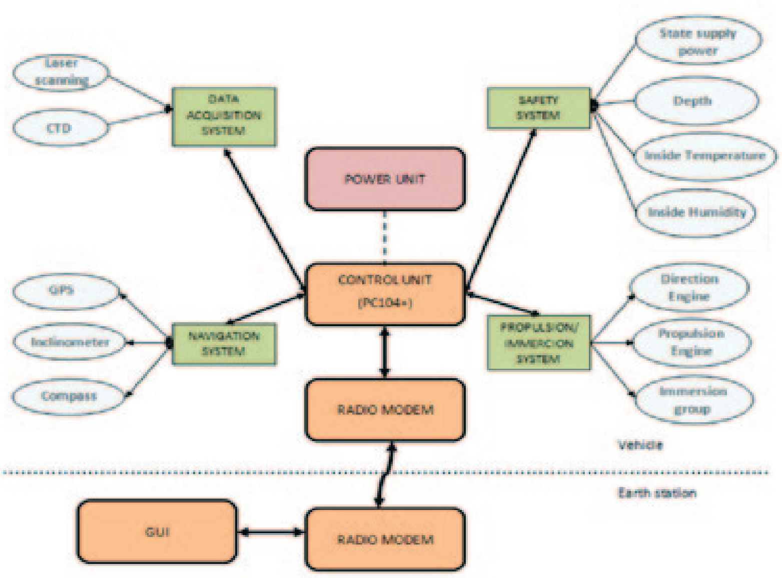

Figure 3. Block diagram of the structure of the control system designed.

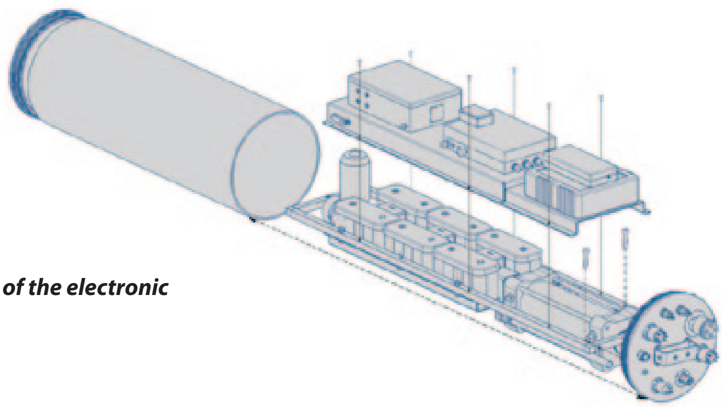

Figure 4. Location of the electronic control system

A. Control Unit

The vehicle is controlled by an embedded computer with Aewin PC104+ assembly [8], model PM_6100. It works with a CPU AMD® Geode™ LX800, 500MHz. It has low energy consumption (max. 12W) with a right size. It operates with Windows XP operating system and the data storage system is a compact flash that provides good protection against vibration. Programming is performed through the graphical programming tool NI_LabVIEW.

B.Navigation System

In order to know the position of the vehicle, it has been equipped with a GPS navigation system. The receiver is the Magallen DG14™ [9], which offers high accuracy by incorporating signal Satellite Based Augmentation Systems (SBAS. Also, the navigation system features a digital compass and a 3-axis altitude indicator integrated in the TCM-2.6 [10].

C.Propulsion Immersion System

The propulsion/immersion system comprises: a main engine, which provides the propulsion, two side engines, which monitor the direction of the vehicle and a pneumatic stainless cylinder allows to dive. The main engine, the Seaeye SI-MCT01-B [11] provides a nominal power of 300W to 960rpm together with the drivers, integrated control and power. The side engines are BTD150 Seabotix [12] engines, providing a maximum thrust of 25N to a maximum power of 80W. For these engines a specific driver was designed for control and power. Finally, the immersion/emersion system is a Festo CRDNG-100-PPV-A pneumatic stainless cylinder [13], controlled by a driver designed specifically for this task.

D.Safety System

The vehicle has been equipped with safety systems that allow monitoring system variables that can become critical to the overall operation. These are:

State of battery charge: is monitored through a RS232 port, indicating the remaining power in batteries by means of a Texas Instruments charge status indicator. This device uses Coloumb Counting control system, to sense the incoming and outgoing energy from the batteries.

Depth: a watertight module of a pressure sensor, GEMS 2200 series with a range of 0-6 bar and a sensitivity of 0.833 (V / bar), has been placed outside the vehicle. This allows us to monitor the depth of the dive between 0m to 60m.

Humidity/Temperature: a humidity and temperature sensor has been placed inside the watertight module to check the level of sealing and to ensure the proper functioning of electronic systems.

E.Radio Modem System

The vehicle is connected to the base station via a radio link, which allows receiving real-time data and vehicle parameter monitoring, making it easier to control. The radio link is a TMOD-C48 Farrell radio modem, [15]. The transmission power is 0.1W to 5W, allowing a maximum range of 10km.

Control System Implementation

All electronic control system of the vehicle is placed in a rack above the battery and immersion system, according to Figure 4. All electronic control system of the vehicle is located inside four PVC boxes. There boxes are distributed on an aluminum support that allows easy handling and installation.

The control unit, located in the first place, has forced ventilation and external connections for the control of the CPU (monitor, mouse, keyboard and USB). Below is a box with regulators switched 12V to 5 V supply. In another box the motor control drivers and the SSC-32 controller were grouped. Finally, the box with the GPS navigation and compass/altitude, the radio modem and the humidity sensor. All PVC boxes were distributed on an aluminium support which enables convenient handling and installation.

All electronic control system designed has been tested and verified by laboratory tests and field trials.

Conclusions

This work provides a control system for an autonomous underwater vehicle. The developed platform is robust, relatively small and lightweight, factors which facilitate its manageability and operability. It incorporates an embedded computer that manages the navigation, propulsion and safety systems of the vehicle. Laboratory testing have shown their proper operation.

Acknowledgements

This work has been funded by the Spanish Ministry of Education and Science and the European Union (FEDER), project nº: CTM2006-12072/MAR.

References

[1]Meyrowitz, A.L.; Blidberg, D.R. and Michelson, R.C. "Autonomous vehicles". Proceedings of the IEEE. Volume 84, Issue 8, pp 1147 – 1164. 1996

[2]Blidberg, D. R. "The development of Autonomous Underwater Vehicles (AUV); A brief summary. Autonomous Undersea Systems Institute publications (AUSI), ICRA, May,2001 Seoul, Korea,.

[3]Dabholkar, N., Desa, E., Afzulpurkar, S., Madhan, R., Mascarenhas, A.A.M.Q., Navelkar, G., Maurya, P.K., Prabhudesai, S., Nagvekar, S., Martins, H., Sawkar, G., Fernandes, P. and Manoj, K.K. "Development of an autonomous vertical profiler for oceanographic studies" Proceedings of the International Symposium on Ocean Electronics (SYMPOL-2007), 11-14 December, 2007.Cochin, India, pp. 250-256.

[4]Byron, J. and Tyce, R. "Designing a Vertical / Horizontal AUV for Deep Ocean Sampling". Proceedings of MTS/IEEE Conference and Exhibition Oceans 2007. Sept. 29 2007-Oct. 4. Vancouver, Canada pp. 1 – 10.

[5]Gomáriz S, Prat, J., Sole J., Gayà P. "An autonomous vehicle development for submarine observation." Journal of Marine Research. VI-2. pp 23-35 August 2009.

[6]Gomáriz, S. Prat, J. Arbos, Viñolo, C. Pallares, O. "Autonomous Vehicle development for vertical submarine observation". International Workshop on Marine Technology. Vilanova i la Geltrú. November 2009.

[7]Gomáriz S, Prat, J., Sole J., Gayà P. "Development of low-cost autonomous oceanographic observation vehicle". Oceans'09 MTS/IEEE. May 2009.Bremen. Germany

[8]Aeewin http://www.aewin.com.tw/main/product_info.aspx?fid=2&sid=3&sname=Embedded+Board&pname=PM-6100&tname=PC%2F104+CPU+Module&fname=&pid=27.

[9]Magellan, http://pro.magellangps.com/en/products/product.asp?PRODID=174.

[10] PNI, http://www.pnicorp.com/products/all/tcm-2-6

[11] Seaeye, http://seaeye.com/thrusters.html.

[12] Seabotix, http://seabotix.com.

[13] Festo. http://www.festo.com/pnf/es_es/products/catalog?action=search&key=CRDNG

[14] Lynxmotion, http://www.lynxmotion.com/Product.aspx?productID=395&CategoryID=52.

[15] Farell, http://www.farell-i.com/farell/eng/productos.php.