Autonomous Surface Vessel based on a Low Cost Catamaran Design

Santiago Puente, Francisco Candelas, Fernando Torres and Dzmitry Basalai
Physics, Systems Engineering and Signal Theory Department, University of Alicante,
Carretera De San Vicente s/n, 03690,San Vicente del Raspeig, Alicante, Spain

Keywords: Marine Robotics, Autonomous Surface Vessel, ASV.

Abstract: Nowadays, Robotics is increasing its importance for the marine environment in our society. It allows to perform surveillance and data sampling tasks reducing the current cost of these tasks. This paper presents the design of a prototype of an Autonomous Surface Vessel (ASV) based on catamaran shape. It uses the screw theory for the propulsion system, which provides high manoeuvrability to the vessel. Furthermore, the parts of the ASV are designed to be printed by a RepRap 3D printer. This gives flexibility to check the performance of the vessel. Also the software control scheme of the vessel is presented.

1 INTRODUCTION

Among the last years, a research focus in Autonomous Underwater Vehicles (AUV) has emerged (Russell B. Wynna, 2014) (Salimzhan A. Gafurov, 2015), and the marine environment is becoming in a good field for research in autonomous robots. Not lot of research have been performed in Autonomous surface vessel (ASV), but this research area is becoming more popular because the necessity to understand marine environment, not only underwater environment, although surface one (Ferri et al., 2015). Nowadays, the coordination of both approaches, underwater and surface one, allows to improve the global understanding of the marine environments (Roberts, 2008). There are a lot of research groups that are developing their own ASV to be used for testing scenarios and algorithms (Pascoal et al., 2000). The majority of that type of vessels are mainly designed for observation and sampling different parameters of the environment (Manley, 1997) (Caccia et al., 2007).

There are a large number of new ASVs that are single hull or catamaran shaped, that provide good hydrodynamic characteristics. Some of them provide a different shape, which allows a better maneouverity (ula Nad et al., 2015). In this paper, a mix among different shapes and control systems is provided in order to design and build a new prototype of ASV. This paper presents a catamaran shape vessel with an screw propulsion which allows it to have a great maneuverity in any direction. Furthermore, another characteristic of the ASV designed is that the hull and others parts of the vessel are built using a 3D printer, what reduces considerable the cost against other manufacturing techniques, and allows fast check of the vessel parts.

Next, in Section 2, the design of the ASV prototype is described. In Section 3 the software architecture of the ASV is presented. The construction results of the ASV are shown in Section 4. Finally, in Section 5, the conclusions are shown.

2 DESIGN OF THE AUTONOMOUS SURFACE VESSEL

The prototype proposed is a vessel based on a catamaran design. It uses two screw traction system (Hunt, 2003) for its propulsion. Another advantage of the presented design is that it is able to move on different types of fluids, due to it's propulsion system. That point provide more flexibility to operate in areas with low level of water, or when a operation starting from shore is necessary. Furthermore, it allows the vessel to stabilise in any position and provides great maneouverity. Other important aspect of the vessel design and implementation that has been considered is the low cost of the vessel and the refurbishment of its parts. In order to accomplish that objective, first the hull and components of the vessel have been modelled using FreeCad (Falck and Collette, 2012), which allow to design all the parts in a fast way. Moreover, this design enables us to print the model in a RepRap printer (Jones et al., 2011) nearly directly. The model

Puente, S., Candelas, F., Torres, F. and Basalai, D.
Autonomous Surface Vessel based on a Low Cost Catamaran Design.
DOI: 10.5220/0005987404520457
In *Proceedings of the 13th International Conference on Informatics in Control, Automation and Robotics (ICINCO 2016) - Volume 2*, pages 452-457
ISBN: 978-989-758-198-4

has been divided in small sections in order to enable the printing by using a popular standard 3D printer with a small working area.

The obtained prototype has a 600mm of length, 450mm of beam and 400mm of heigh. The catamaran is supported on two hulls of 600mm of length. These hulls compose the main part of the ASV. They are used like the basement of ASV and for storage the power supply and required sensors for the possible missions. Figure 1 represents the 3D model of the hull with the division required to print it by the 3D printer. The same happens to the parts of the ASV that are greater than 200mm, which is the biggest print size that allow the printer used.

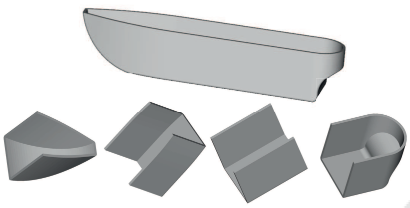

Figure 1: Hull and parts for 3D printer.

Other part of the vessel is the propulsion system which is based on the screw theory. The ASV proposed has two propellers in screw shape which allows to control the movement of the vessel in any direction according the rotation direction and speed of each motor (Figure 2). The movement of the vessel is generated when port motor and starboard motor generate a forward direction thrust. Each motor generates a rotation r_1 and r_2 with provide the forces F_1 and F_2 respectively, which moves forward the vessel. If both, port motor and starboard motor, rotates in backward direction, generate a rotation r_3 and r_4 which provide the forces F_3 and F_4 respectively, moving the vessel backward. It is possible generate a yaw rotation movement with stable holding position by using a combination of different speeds for port and starboard motor.

The port and starboard motors are design to be fit inside a case, with a gearbox, bearings, and the necessary seals for avoiding water to fill in the motor space (Figure 3). When the motor rotate, it generates a movement in the gearbox which increase the torque to move the case. This case acts as a propeller thanks to it has a screw shape in its outside face. The two sets of motors and gear-boxes have been obtained from cheap battery screwdrivers. Furthermore, in the front part of the case, a tube has been used to hold the case to the hull of the vessel, and wires to the motor are contained in this tube. This tube has a bearing around it to allow the case to rotate with the motor axis and leaving the motor static. Thanks to this design, it is not necessary to drive any mechanical transmission of movement from the vessel to the propeller. Besides, only two wires to give the power to the motor are necessary from the vessel to the propeller. This simplifies largely the mechanical design. The case and the connectors are designed to be printed using the 3D printer.

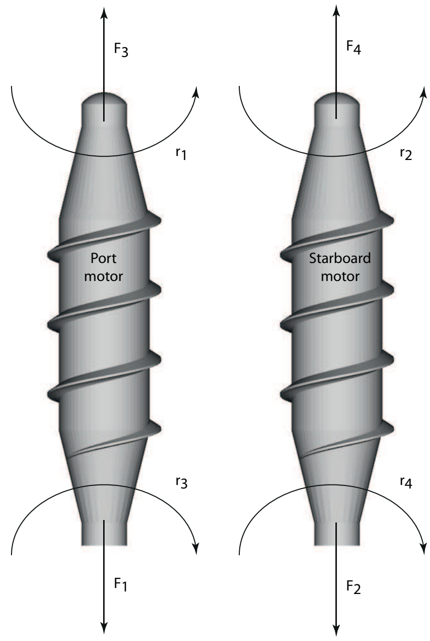

Figure 2: Propulsion vectors system for vessel movement.

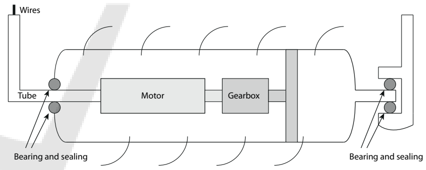

Figure 3: Port and Starboard motor design.

After the design of the ASV was performed, the control and software architecture of the system were detailed. The designed vessel uses the control scheme architecture shown in Figure 4. The architecture is divided in two main parts: base control station and onboard control system. The base control station uses a Laptop as main control core. it is used for high level veseel control and general acquisition. It communicates with a Arduino board through a serial-USB port which provides the communication thought Xbee module with the onboard control system. The main core of the onboard control system is a phone. A Android based mobile phone, which, which is used to provide GPS coordinates to obtain the location of the vessel in any moment. Furthermore, it provides the intelligence embedded in the ASV. The use of a mobile phone provides low cost sensors, communication system and computation power. Furthermore, the phone is used to calculate current destination azimuths and distances between two locations points. To communicate with the base control station, a XBee module is used, which is connected to an Arduino ADK. The Arduino ADK receives data from phone and transmits it through Xbee module to base control station. This communication is in both senses. A XBee module based on technologies such as Zigbee or 802.15.4 provides a line-of-sight range larger that other radio options like WiFi (Lee and Lin, 2016). Furthermore, XBee communication solves the problem. This solves the problem of using GSM communication has with places with low or null coverage. In addition, the Arduino ADK provides communication with motor driver board to control motor operation according to required trajectory. A high efficiency VNH5019 motor driver based on MOSFET from ST Microelectroncis has been used, which allows to control the current and speed of the two motors, port and starboard ones, by means of PWM signals. The control signal is generated using a PWM signal as reference. The motor driver allows the control of both motors, the port and starboard ones.

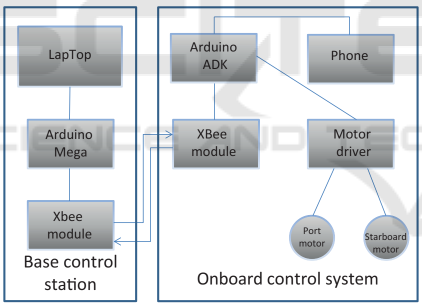

Figure 4: Architecture control scheme of ASV.

3 SOFTWARE SYSTEM

The software system has two main modules, one in the base control station and the other in the onboard control system. The base control system has to perform the following main task, as shown in Figure 5:

- Receive current location information (longitude, latitude, speed, accuracy, bearing, altitude) from onboard control system.
- Sending target trajectory information to the onboard control system.
- Show vessel information in the user interface.
- Interact with the user to process his commands.

The information from the vessel is received by the XBee module and passed to the Arduino, whose only task is to validate and retransmit the information to the laptop, which is the responsible of processing it and showing in the user interface.

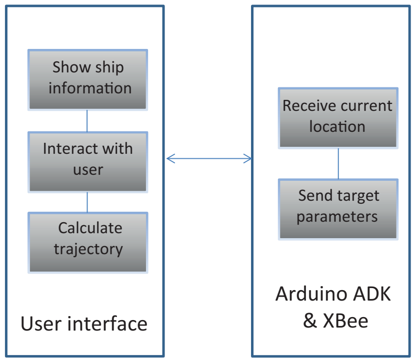

Figure 5: Software base control station scheme.

Onboard control system has to perform the next tasks that are represented in Figure 6:

- Establish connection between onboard control system and base control .
- Obtaining current location information (GPS coordinates).
- Computing current navigation parameters: longitude, latitude, speed, accuracy, bearing, altitude.
- Receiving trajectory information from base control system.
- Calculate orientation and thrust to the target.
- Send onboard information to base control system.
- Control the motors to perform achieve the target.

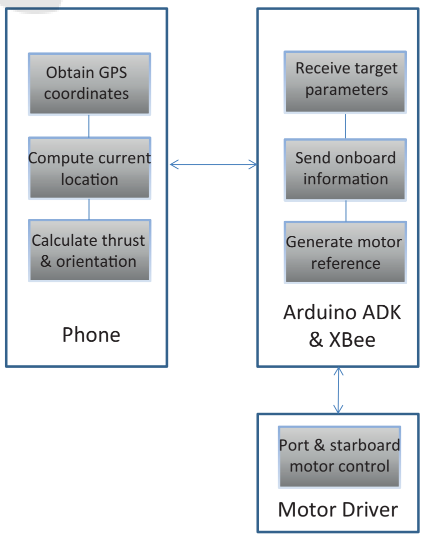

Figure 6: Software onboard control system scheme.

These tasks are performed by the phone and by the Arduino ADK. The current location information and the required orientation and thrust of the vessel to achieve the target location is computed by the phone. It uses information from the base control station and from its own sensors. The information obtained is transmitted to the Arduino ADK, which has to send the onboard information to the base control system and has to generate the control signals for the motor driver.

3.1 User Interface

The user interface has been programed by using Microsoft Visual Studio, providing a Windows application to control the ASV. It is located in the base control station. The application allows the control of the ASV in two modes: manual and automatic. In manual mode, the operator controls each motor directly. While the application is in automatic mode, the operator sends geographical references through a map and the onboard control system perform the control of the ASV to reach the target reference.

The user Interface for the ASV is shown in Figure 7. The parts of the interface are:

1. Received data: Field for received data from onboard control system (longitude, latitude, speed, altitude, accuracy, angle, etc) .
2. Operation mode: It allows user to choose type of operation of ASV(automatic or manual).
3. COM Port: Field for selecting the serial port in which is connected the Arduino Mega. It allows user to stablish or not communication between user interface and Arduino.
4. Map: Field to display the current position in a map. The map is obtained from Google Maps using the location of the vessel.
5. Field of operation in different modes (Auto Mode/Manual mode) and adjust the PID parameters. It allows to send information to onboard control system through Arduino ADK (latitude and longitude of desired point) based on the operation parameters like: PID adjustments, controlling commands of ASV in manual mode. Furthermore, it allows to receive information from onboard control system (azimuth, distance)
6. Speed motor manual monde: Field to display graphs of location in manual and automatic mode (speed and azimuth).
7. Debug information: Field for debugging and future instalation of a webcam in the ASV.

3.1.1 Manual Mode

The manual mode is one of the working modes of the ASV. In this mode the user can control the vessel with the control shown in Figure 8. This mode have two working ways. Fisrt, the ASV control of the trajectory, where the user can control the direction of the movements of the vessel. Second, the direct motor control, where the user can control the speed of each motor of the vessel. Furthermore, in the second mode the user can connect or disconnect each motor independently.

3.1.2 Automatic Mode

The automatic mode. Figure 9 shows the layout of the interface that allows user to input commands for the automatic mode. In this mode the target point and the speed required have to be indicated by the operator. These information can be introduced directly or by clicking in the map. The automatic mode a frame shows the azimuth required to achieve the target location and whole distance to it.

3.1.3 PID Adjustment

The vessel on-board system has one PID controller to control motor speed based on information provided by the based control system. The vessel has other independent PID controller to generate trajectory references and transform them to thrust and azimuth required by on-board control system. Figure 10 shows a interface form that allows user to specify the parameters K_p, T_i and T_d of each PID controller.

4 CURRENT RESULTS AND FUTURE WORK

The result of the work presented in this paper is an ASV (Figure 11) which a great manoeuvrability and an interface which provide the operator a good control of the system.

The ASV has been tested in laboratory environment to check that all part of the ASV responds properly. All the parts of the vessel have been printed and assembled, adding the electronics components and motors to the system. The communication system has been tested with good results and the motors responds properly to user commands. Furthermore, the waterproof and buoyancy of the ASV has been checked with positive results. The next phase will be to check the vessel on water environment, lake or sea to perform a real task.

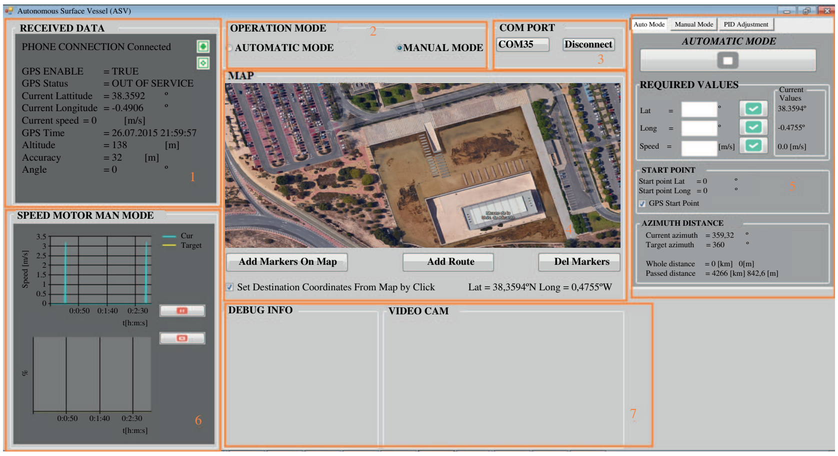

Figure 7: User interface.

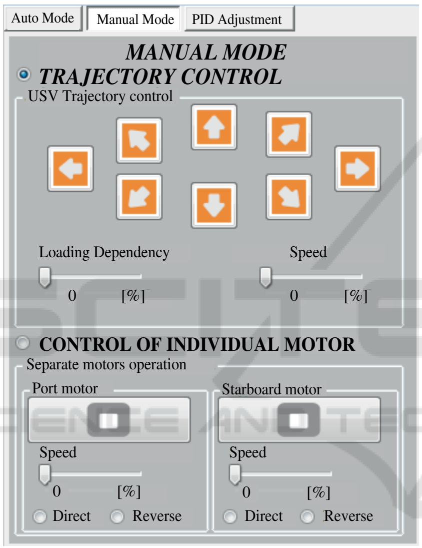

Figure 8: User interface: Manual mode.

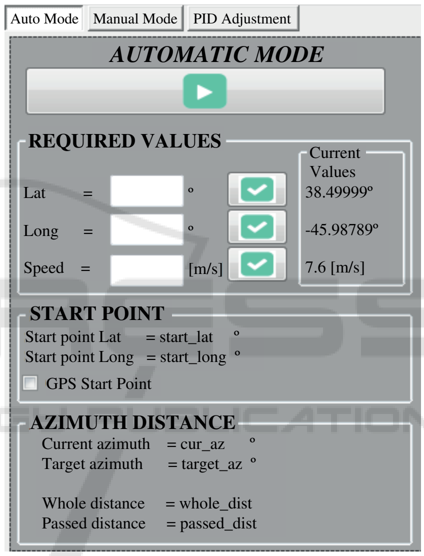

Figure 9: User interface: Automatic mode.

5 CONCLUSIONS

The designed ASV prototype provides a different approach from the existent vessels. It is focused in providing great manoeuvrability and reducing the costs of building the parts of the vessel by using a low-cost 3D printer. Also, components including motors and electronics are cheap and easy to find. Another advantage of the presented design, as was mentioned before, is that it can move in different types of surfaces. This advantage allows the vessel to start a operation mission from the shore.

One of the main problems of this prototype was the necessity of dividing the model of the vessel in several parts to allow us to print it. This could be improve using a bigger 3D-printer that allows us to print more than 1000mm length prototypes to be printed.

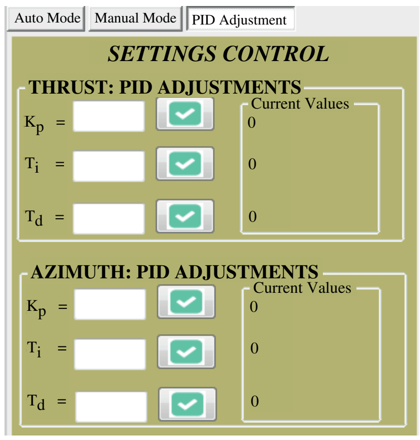

Figure 10: User interface: PID adjustment.

Figure 11: Final prototype of the ASV.

The long distance radio systems allows an automatic or manual operation of the vessel. Furthermore, in the automatic mode the vessel has autonomy to arrive the target point. Another important aspect of vessel is the motor design. It presents a simple and robust mechanical structure.

The ASV presented here is a fully equipped platform suitable for many marine research tasks. For developing specific research the required sensors can be added. Moreover, to perform more complex task, a high level control system is required. It will allow the operator to indicate the desired task. We are working to improve this point now.

ACKNOWLEDGEMENTS

The research leading to these result has received funding from the Spanish Government (DPI2015-68087-R) and Valencia Regional Government (PROMETEO/2013/085).

REFERENCES

Caccia, M., Bibuli, M., Bono, R., Bruzzone, G., Bruzzone, G., and Spirandelli, E. (2007). Unmanned surface vehicle for coastal and protected waters applications: the charlie project. *Marine Technology Society Journal*, 41(2):62–71.

Falck, D. and Collette, B. (2012). *FreeCAD [How-to]*. Packt Publishing.

Ferri, G., Manzi, A., Fornai, F., Ciuchi, F., and Laschi, C. (2015). The hydronet asv, a small-sized autonomous catamaran for real-time monitoring of water quality: From design to missions at sea. *Oceanic Engineering, IEEE Journal of*, 40(3):710–726.

Hunt, K. H. (2003). Review: Don't cross-thread the screw!*. *Journal of Robotic Systems*, 20(7):317–339.

Jones, R., Haufe, P., Sells, E., Iravani, P., Olliver, V., Palmer, C., and Bowyer, A. (2011). Reprap the replicating rapid prototyper. *Robotica*, 29:177–191.

Lee, H. C. and Lin, H. H. (2016). Design and evaluation of an open-source wireless mesh networking module for environmental monitoring. *IEEE Sensors Journal*, 16(7):2162–2171.

Manley, J. E. (1997). Development of the autonomous surface craft ldquo;aces rdquo;. In *OCEANS '97. MTS/IEEE Conference Proceedings*, volume 2, pages 827–832 vol.2.

Pascoal, A., Oliveira, P., Silvestre, C., et al.. (2000). Robotic ocean vehicles for marine science applications: the european asimov project. In *OCEANS 2000 MTS/IEEE Conference and Exhibition*, volume 1, pages 409–415 vol.1.

Roberts, G. (2008). Trends in marine control systems. *Annual reviews in control*, 32(2):263269.

Russell B. Wynna, Veerle A.I. Huvennea, et al. (2014). Autonomous underwater vehicles (auvs): Their past, present and future contributions to the advancement of marine geoscience. *Marine Geology*, 352:451–468.

Salimzhan A. Gafurov, E. V. K. (2015). Autonomous unmanned underwater vehicles development tendencies. *Procedia Engineering*, 106:141–148.

ula Nad, Mikovic, N., and Mandic, F. (2015). Navigation, guidance and control of an overactuated marine surface vehicle. *Annual Reviews in Control*, 40:172 – 181.