Design of SPARUS II AUV

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Abstract

This report describes the main features of the SPARUS II AUV, which has been designed at the University of Girona as a lightweight vehicle combining the classical torpedo-shape features with the hovering capability. The robot has a payload area to allow the integration of different equipment depending on the application. The software architecture is based on the ROS open source framework which allows an easy integration of many devices and systems. The basic architecture is available on the web and can be simulated using UWSIM. Its flexibility, easy operation and openness makes the SPARUS II AUV a multipurpose platform that can adapt to industrial, scientific and academic applications.

1 INTRODUCTION

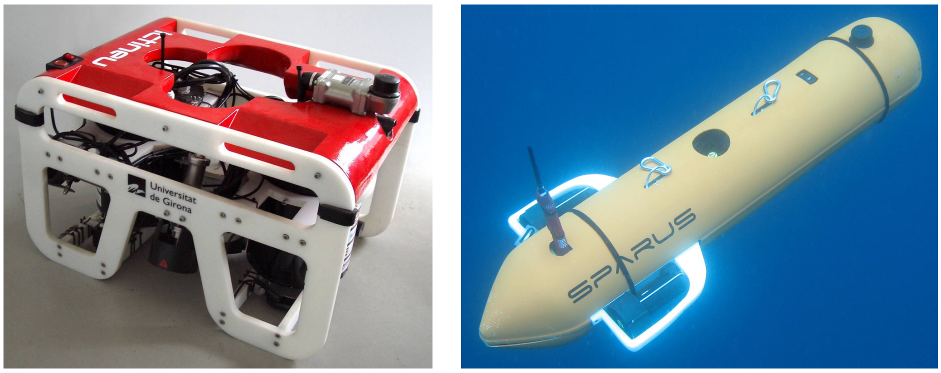
Commercial AUVs are mainly conceived for surveying applications in which large areas must be covered and the vehicle follows safe paths at safe altitudes. However, new advances in sonar technology, image processing, mapping and robotics will allow more complex missions, in which the AUV will be able to navigate at a closer distance from the seabed, it will react to the 3D shape of the environment, and it will perform some autonomous intervention tasks. In this context, the Underwater Robotics Research Centre of the University of Girona has developped several AUV prototypes during more than 15 years to achieve these new capabilities.

Two of the vehicles were developed in the context of the Student Autonomous Underwater Competition vehicle Challenge - Europe (SAUC-E), in 2006 and 2010, see Figure 1. Both of them won the competition [1, 2] demonstrating robustness, functionality and flexibility for performing the different tasks of the competition. Both vehicles, ICTINEU AUV and SPARUS AUV, have been used, after the competition, as platforms for doing experiments in research projects. The vehicles have been upgraded by improving the original systems and by adding state of the art equipment. Also, the laboratory has recently designed another hovering AUV vehicle, the GIRONA 500 AUV [3] in 2011, which has demonstrated to be a multipurpose operative platform working at 350 meters in Greece for a survey mission in 2012 and performing autonomous intervention tasks in a harbor environment in Spain in 2012, for giving two examples.

This report presents its last design, the SPARUS II AUV see Figure 2, which is the second version of SPARUS AUV. The main concept of the vehicle is a lightweight AUV, easy to deploy and to operate, with good efficiency and hovering capability and with some payload area that allows an easy integration of different equipment for multipurpose industrial, scientific and academic applications.

2 SPARUS II DESIGN

SPARUS II AUV has followed the basic configuration than it predecessor SPARUS, see Figure 3. The main features and specifications of the vehicle can be found in Table 1. It has a torpedo-like shape following a Myring hull profile [4] to be efficient when navigating at medium/high velocities. The estimated maximum velocity in surge is between 3 and 4 knots. It has 3 thrusters (2 horizontal and 1 vertical) that allow the control of the surge, heave and yaw Degrees of Freedom (DoFs) when moving in hovering mode. In torpedo-based mode, the two fins behind the horizontal thrusters are used for controlling the pitch DOF and thus controlling the depth or altitude of the vehicle. The fins can also be used to maintain a stable angular position



(a) ICTINEU AUV (b) SPARUS AUV

Figure 1: AUVs developed by the University of Girona for the SAUC-E competition. Winners of the 2006 and 2010 editions of the competition.

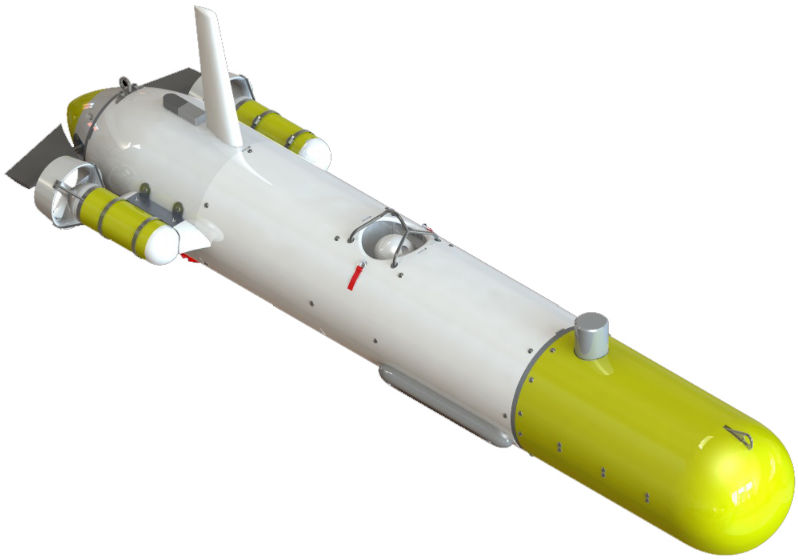


Figure 2: Rendering of SPARUS II.

in roll DOF. Therefore, the robot is designed to be efficient when moving fast using the two horizontal thrusters and the two fins for controlling surge, pitch and yaw DOFs. The vertical thruster is not used in this mode, since the fins are able to control the depth of the vehicle more efficiently. Then, the robot can keep position or can move slowly using the vertical thruster for counteracting the buoyancy and floatation forces, thus acting as a normal hovering UUV. It is also interesting to note that, in hovering mode, the two fins will still be active for having a zero pitch position, and this stabilizes the vehicle a lot specially in heave and surge movements.

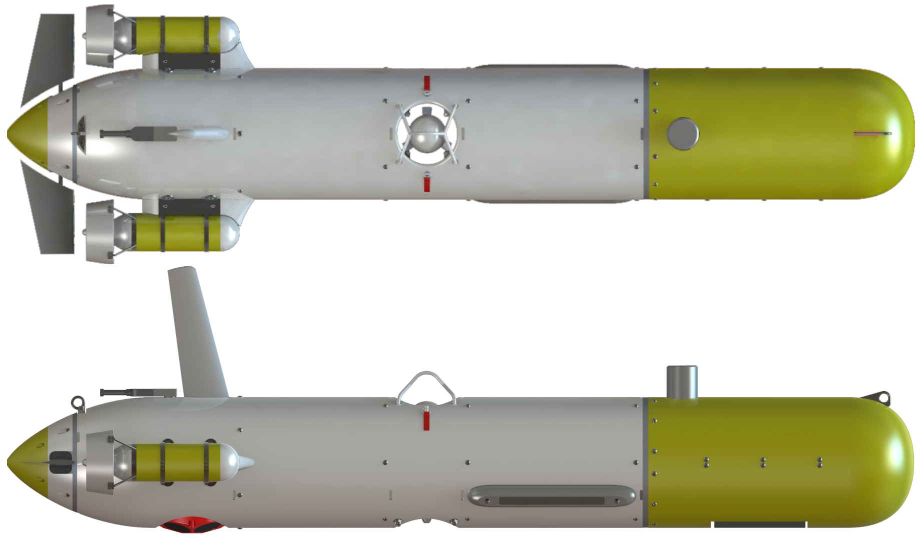


Figure 3: Top and lateral view of SPARUS II.

The hull has been designed having a main closed housing and an open payload area in front. The maximum depth of the vehicle is 200 meters, for which aluminium and acetal were chosen. In Figure 3, the front payload area is shown in yellow. The main housing is represented in white. This housing is assembled with two cylinders, a special part for the vertical thruster and another special part for back cone, where horizontal thrusters, DVL and antenna are placed. Two end-cups are used in front and on the back for closing the main hull, having some underwater connectors for different purposes. Another special part is attached to the back end-cup, which contains the two servo-motors for the fins. The main idea behind the design of the hull is that the internal electronics is attached to the central part, the one containing the vertical thruster. When disconnecting the front end-cup and the back cone part, the two cylinders can be removed and all the electronics is accessible. The electronics and all the cables do not have to be moved or pulled to open the vehicle, and this improves a lot the robustness of the system. Also, it is not necessary to open the front and back part of the main hull at the same time, just the one we need to work. The only thing that has to be done, before removing the two cylinders, is to disconnect three multi-pin industrial connectors. It is possible to connect them again without the cylinders for testing the electronics with all systems connected. The payload area has been designed to be flexible to many equipment requirement, see Figure 4. It has an external structure that it is used to attach the equipment, the foam and the external skin. The external skin is built on a

Table 1: SPARUS II specifications

Length	1.6 m
Hull diameter	230 mm
Max width	460 mm
Weight in air	52 Kg
Maximum depth	200 m
Energy	1.4 kWh Li-Ion batt.
Endurance	8-10 hours
Max surge velocity	3-4 knots
Propulsion system	3 thruster (magnetic coupling) and 2 fins
DoFs	surge, heave, pitch, roll and yaw
Structure	modular aluminium and acetal hull
Software	Linux Ubuntu and ROS
Navigation	DVL, IMU, pressure sensor and GPS
Payload area	8 liters - 7 kg in air available
Payload interface	Ethernet, RS-232 / regulated 12V and 24V
Communications	WiFi, Xbee, GSM/3G, acoustic modem
Safety	Emergency primary batt., independent pinger tracking system, flasher light, USBL and acoustic modem.

mold with ABS plastic. For each equipment, a new skin can be adapted by cutting the plastic with the required apertures. Finally, the front end-cup has several underwater connectors for different equipment requirements.

Another important aspect on the design of the vehicle is the security of the platform. The vehicle is powered by a 1.4 kWh pack of Li-Ion batteries which is controlled by a Battery Management System (BMS) to ensure the safety of the pack when charging and discharging. All the cells are monitored by the BMS and the onboard computer receives the state of the pack continuously. The estimated endurance of the batteries, depending on the velocity of the vehicle, is between 8 and 10 hours. There is also a primary emergency non-rechargeable battery that will power a reduced set of electronics in case of main battery failure. This set of electronics includes a GPS, a GSM/3G connection, a Xbee radio link, a flasher light and an acoustic modem with USBL positioning. Additionally, there is an independent acoustic pinger tracking system. These devices will be used to transmit or detect the position of the vehicle either if it is at the surface level or in the water column.

Besides the security electronics, the robot has a PC104 embedded com-

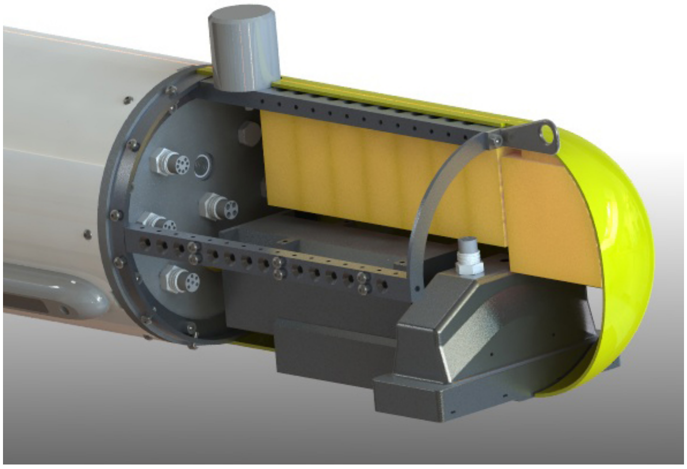


Figure 4: Payload area view containing an aluminium structure, foam, two sensors, underwater connectors and the vehicle ABS skin.

puter that manages all the systems in normal operation mode. The computer runs an Ubuntu Linux distribution with the ROS open framework which standardizes the integration of new devices or systems and opens the software to any user. An underwater simulator, see Figure 6, is also available for preparing the missions and testing the algorithms using the Underwater Simulator UWSim [5]. Both, the software architecture and UWSim, are available to the interested users on the web. The computer uses a RS485 serial communication for controlling the 3 thrusters, which have been designed also by the University of Girona. Each thruster provides up to 6 kg of force using a brushless DC motor with a magnetic coupled ducted propeller. The same serial line is used to control the two fins using servomotors connected by means of a sealed axis. In case of a water leakage, the servomotors are contained in an independent part which is not connected internally to the main hull housing. For navigation, the robot uses an IMU from Analog Devices, a pressure sensor from Keller and an OEM DVL from LinkQuest, which is integrated in the back cone part. Other DVL units can be integrated, such as the OEM RDI Explorer DVL. A sidescan sonar from Imagenex is integrated in the front cylinder and, finally, an OEM acoustic modem with USBL from Evologics is integrated in the payload area. All the system is switched on by a magnetic switch and by a remote controller. The internal computer can be connected by wifi or using an umbilical cable. Another cable is used for recharging the batteries. Application specific equipment is installed in the payload area, having also space inside the main hull for internal electronics. Regulated 12V (max power 40W) and 24V (max power 100W) and ethernet and RS232 serial communication is available for new equipment. Connections are done using underwater connectors (Subconn compatible) which can be used for any required need. The payload can have up to eight connectors. When not all of them are used, some screws are used for closing the holes. The platforms developed in this contract will have three underwater connectors, each one having an ethernet and an independent RS232 serial interface and 12V o 24V. Additional or specific connections, or higher power requirements, can be studied and integrated. Examples of sensors that can be integrated are: Imagenex multibeam profiler sonar (see Figure 5), BumbleBee stereo camera, Seabird CTD, Imagenex echosondas for obstacle avoidance, Blueview forward looking sonar.

The payload area can integrate any equipment having a maximum volume of 8 liters and a maximum weight of 7 kg. The non-required volume or weight is filled by foam and lead to maintain a constant total volume and weight, which is approximately 52 liters and 52 kg in air. The size and weight is similar than conventional gliders and, therefore, the deployment and recovery of the vehicle can be done by a team of 2 persons from a small boat without requiring a crane.

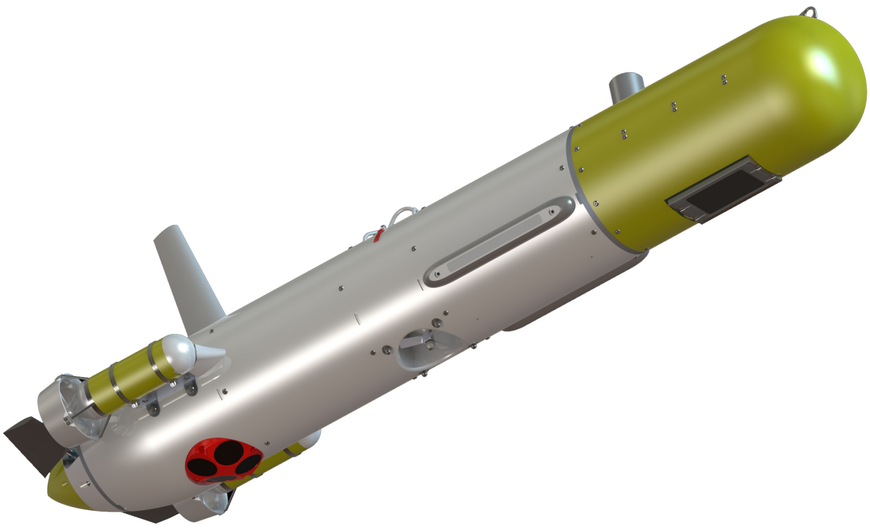


Figure 5: Bottom view. Configuration with DVL, sidescan sonar, acoustic modem and multibeam.

3 CONCLUSIONS

This report has summarized the main features of SPARUS II AUV. The design phase of the vehicle was finished in summer 2013 and the tests of the vehicle were conducted in autumn 2013. The vehicle size, weight, maneuverability, efficiency, autonomy and payload area makes the robot an excellent platform for industrial, scientific and academic applications. The open software architecture, based on ROS, and the simulator, based on UWSim, allow an easy integration of new equipment and systems. An open source version of the software architecture is available to the community.

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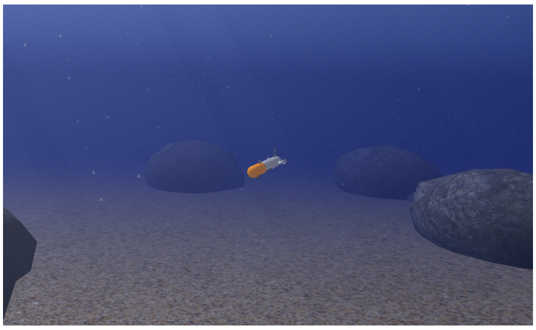

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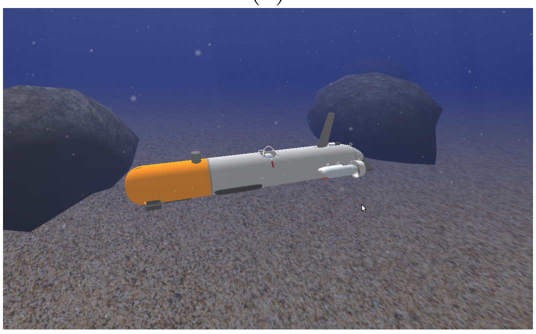

(b)

(c)

Figure 6: Views of SPARUS II simulated in UWSim.