

M5 SPARUS II, DESIGN OF A LIGHTWEIGHT HOVERING AUV

Marc Carreras¹²⁶, Carles Candela¹⁵⁷, David Ribas¹⁵⁸, Angelos Mallios¹⁵⁹, Lluís Magí¹⁶⁰, Eduard Vidal¹⁶¹, Narcís Palomeras¹⁶², Pere Ridao¹⁶³

Abstract

This paper 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 ROS, an open framework that allows an easy integration of many devices and systems. Its flexibility, easy operation and openness makes the SPARUS II AUV a multipurpose platform that can adapt to industrial, scientific and academic applications.

Keywords – Autonomous Underwater Vehicle, vehicle design, hovering Unmanned Underwater Vehicle.

I. INTRODUCTION

Commercial AUVs are mainly conceived to 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 even perform some autonomous intervention tasks. In this context, the Underwater Robotics Research Centre of the University of Girona has been developing several AUV prototypes during more than 15 years to achieve these new capabilities. This paper presents its last design, the SPARUS II AUV, which is the second version of SPARUS AUV, winner of the SAUC-E 2010 competition [1]. 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. The design of SPARUS II has been based on the good results obtained with its "big brother" GIRONA 500 [2], another AUV built in the laboratory in 2011 conceived for applications requiring a much more stable platform and a bigger payload area. This paper presents the design of the vehicle, which is now being constructed and will start being operative at the end of 2013.

II. SPARUS II DESIGN

SPARUS II AUV (Figures 1 and 2) has followed the basic configuration than its predecessor SPARUS. The main features and specifications of the vehicle can be found in Table I. It has a torpedo-like shape following a Myring hull profile [3] 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. Finally, the fins can also be used to maintain a stable angular position 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. For more information on the SPARUS II design refer to the full paper.

III. CONCLUSIONS

The design phase of the vehicle has finished and the first test of the vehicle is expected on autumn 2013. The vehicle size, weight, maneuverability, efficiency, autonomy and payload area makes the robot an excellent platform for multiple applications. The open software architecture, based on ROS, allows an easy integration of new equipment and systems. Finally, a simulator framework and an open source version of the software architecture will be available to the community.

IV. ACKNOWLEDGEMENTS

This research was sponsored by national (COMAROB project - DPI2011-27977-C03-02 and RAIMON project - CTM2011-29691-C02-02) and European projects (PANDORA project - FP7-ICT-2011-7-288273 and MORPH project - FP7-ICT-2011-7-288704).

REFERENCES

- [1] V. Djapic and T.B. Curtin. SAUC-E: Fostering the Next Generation of Scientists and Engineers. *Robotics & Automation Magazine, IEEE*, 18(3): 10-14, 2011.
- [2] D. Ribas, N. Palomeras, P. Ridao, M. Carreras and A. Mallios. Girona 500 AUV, from survey to intervention. *IEEE/ASME Transactions on Mechatronics*, 17(1):46-53, February 2012.
- [3] D. Myring. "A theoretical study of body drag in subcritical axisymmetric flow." *Aeronautical Quarterly*, vol. 27, no. 3, pp. 186-194, 1976.

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.

Table 1. SPARUS II specifications

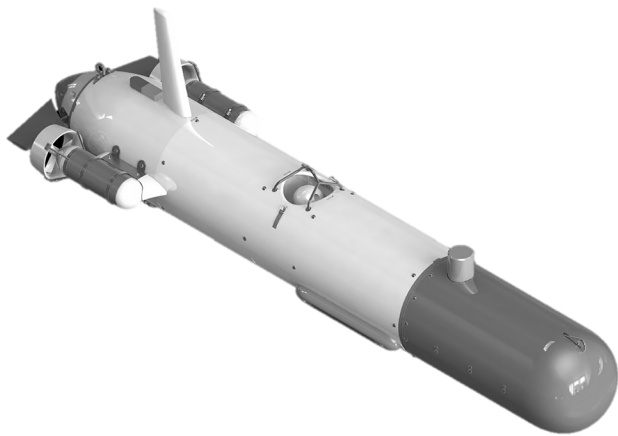


Figure 1. SPARUS II AUV design

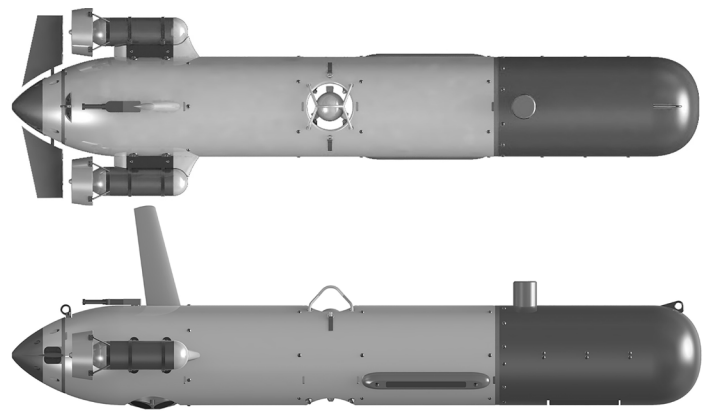


Figure 2. Top and lateral view of SPARUS II.

M5 TOWARDS REALTIME AUV SLAM WITH OCCUPANCY GRIDS

Guillem Vallicrosa¹⁶⁴, Albert Palomer¹⁶⁵, David Ribas¹⁵⁸, Pere Ridao¹⁶³

Abstract

This paper describes a Realtime Terrain Based Navigation algorithm designed for the Girona500 AUV and tested in a water tank. This paper seeks to establish the foundations for a future online SLAM and planning. Realtime TBN is achieved by means of a parallelized Particle Filter and a fast query and insertion map 3D Occupancy Grid representation using Octomap library. Particle Filter is implemented as a single ROS node in the vehicle's software architecture with a motion model based on AHRS-DVL and measurement model based on a multibeam sonar profiler sensor. Several parameters of the particle filter are studied as well as its realtime performance.

Keywords – Terrain Based Navigation, Autonomous Underwater Vehicle, Octomap, Particle Filter, multibeam.

I. INTRODUCTION

Terrain Based Navigation (TBN), is the name used by the marine robotics community to refer to the more general problem of mobile robot localization with a known map. In particular, TBN solves for the robot pose given an a priori known map, fusing information from dead reckoning navigation with map referenced observations. The principle is the same as has been used for centuries: Localize the vehicle based on observations of known characteristics of the map. TBN has been mainly applied to aerial and underwater vehicles. During the last years the accuracy and extension of the maps has been increased considerably, and TBN has been adopted as a method to complement inertial navigation system (INS), as an alternative when GPS is not available. Underwater, TBN is still at a research stage, not having evolved into a commercial product. During the last

two decades, the scientific community working with mobile robots, has pushed forward the boundaries of the knowledge facing an even more challenging problem: the Simultaneous Localization and Mapping. Both SLAM and TBN have a great potential to improve the autonomy of the underwater vehicles, allowing AUVs to freely move abroad the areas of coverage of the acoustic transponder networks.

Using navigation sensors it is possible to measure the robot velocity, acceleration and attitude, to be used as the input for the dead reckoning equations needed to compute the robot pose. Due to the noisy measurements, the position estimate will rapidly grow without bounds. TBN takes advantage of existing digital terrain maps of target area, where the vehicle shall navigate. Conventional dead reckoning navigation methods provide a prior estimate of the robot pose within the map. Then, using exteroceptive sensors, terrain observations are obtained to be correlated to the a priori known map in order to compute the robot pose.

$$p(\bar{x}_t) = \int p(x_t | x_{t-1}, u_t) p(x_{t-1}) dx_{t-1} \quad (1)$$

$$p(x_t) = \eta p(z_t | x_t) p(\bar{x}_t) \quad (2)$$