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Development of the Pirajuba AUV

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Abstract: This work introduces the Pirajuba vehicle, an autonomous underwater vehicle that has been developed at the University of Sao Paulo. The paper describes its main systems, emphasizing hardware and software control architectures. The embedded system is low cost and based on off-the-shelf components, and on free and largely known software tools, like C language, and GNU compiler. Results of preliminary tests in a swimming pool are also presented, demonstrating the real-time operation of the AUV.

Keywords: real-time, control architecture, underwater vehicles, AUV, CAN.

1. INTRODUCTION

The Pirajuba project deals with development of a low cost AUV for investigations on dynamics and navigation of this class of vehicle.

The vehicle geometry (Fig. 1) was inspired by Maya AUV, which was developed under a joint Indian-Portuguese project that also included the cooperation with the Unmanned Vehicles Laboratory at University of Sao Paulo for manoeuvrability studies. Main differences to Maya include the hydroplanes configuration (in Pirajuba, it is adopted the cruciform type located at rear end of middle body), a free flooding construction, a customized thruster, and all embedded hardware and software systems.

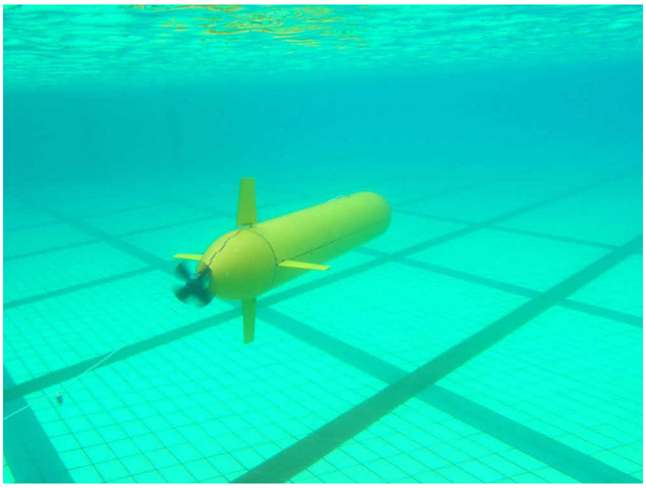

Figure 1. Pirajuba AUV during tests in a swimming pool.

The original application of this AUV is experimental support to studies on predictions of hydrodynamic derivatives. This investigation started with application of analytical and semi-empirical, ASE, methods to predict derivatives of the Maya AUV (de Barros et al. 2004, 2006 and 2008a). In a latter phase, the ASE methodology has been integrated to CFD tools in order to improve the derivative predictions (de Barros et al. 2008b). Up to now, towing tank tests were used for validation of static derivatives prediction. The use of free model tests with Pirajuba is aimed to include validation of dynamic derivatives prediction as well, and to reduce the costs of experiments.

The common type of shape related to Myring geometry (Myring, 1976), which is present in vehicles such as Remus and Maya, makes Pirajuba an useful test bed for studies on AUV hydrodynamics and control. In this sense, similarly to the case of joint investigations on ship manoeuvring, this shape can be adopted as a reference for tests in different institutions.

This AUV is also aimed to be used as a platform for academic investigations and technological practicing in the field of underwater technology, and embedded systems.

This work emphasizes the characteristics of embedded control architecture. A significant departure from the original system proposed for this AUV (Amianti and de Barros, 2008) is proposed in order to simplify the software development and hardware implementation.

This paper is organized as follows. Section 2 gives an overview of the AUV. Section 3 introduces the control hardware of Pirajuba. Section 4 describes the software control

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architecture that is in use. Finally, section 5 provides a critical review of the progress achieved so far and proposes future developments for the AUV project.

2. THE VEHICLE MAIN FEATURES

Pirajuba is a cruising type AUV designed for having autonomy of 4 hours at 2m/s. The main particulars of the vehicle are given in table 1.

Table 1. Main Parameters Of the hull

Bare Hull Length (m)	1.742
Hull Maximum Diameter (m)	0.234
Base Diameter (m)	0.057
Nose Length (m)	0.217
Middle Body Length (m)	1.246
Myring Body Parameter θ (°)	25
Myring Body Parameter n	2

The bare hull is composed by a nose section, a middle body cylindrical section, and a tail section. The nose shape and the tail shape are described by modified semi-elliptical radius distribution (Myring, 1976),

$$r(x) = \frac{1}{2} d \left[1 - \left(\frac{x - nl}{nl} \right)^2 \right]^{1/n} \tag{1}$$

, and the cubic relationship

$$\begin{aligned} r(x) &= \frac{1}{2} d \\ &- \left[\frac{3d}{2(100 - nl - cl)^2} - \frac{\tan\theta}{(100 - nl - cl)} \right] (x - nl - cl)^2 \\ &+ \left[\frac{d}{(100 - nl - cl)^3} - \frac{\tan\theta}{(100 - nl - cl)^2} \right] (x - nl - cl)^3 \end{aligned} \tag{2}$$

, respectively, where

- x is the axial distance to the nose tip,
- d is the maximum hull diameter,
- nl is the nose length,
- cl is the middle body length,
- θ, the Myring parameter, is the tail semi-angle.

The hydroplanes are formed by all movable control surfaces with the section NACA 0012. Details are given in Table 2.

Table 2. Main Parameters of the hydroplanes

	Dimensions (m)
Span	0.554
Exposed Semi-Span	0.016
Root Chord	0.090
Tip Chord	0.060
Distance from the leading edge to the hull nose tip	1.373

In the Fig. 2, it is presented a drawing of the vehicle and the hydroplanes layout.

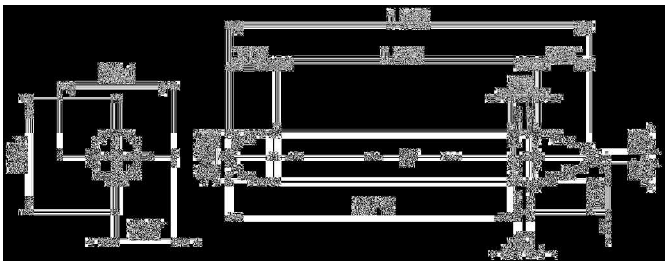

Figure 2. Representation of the AUV particulars (dimensions are in mm).

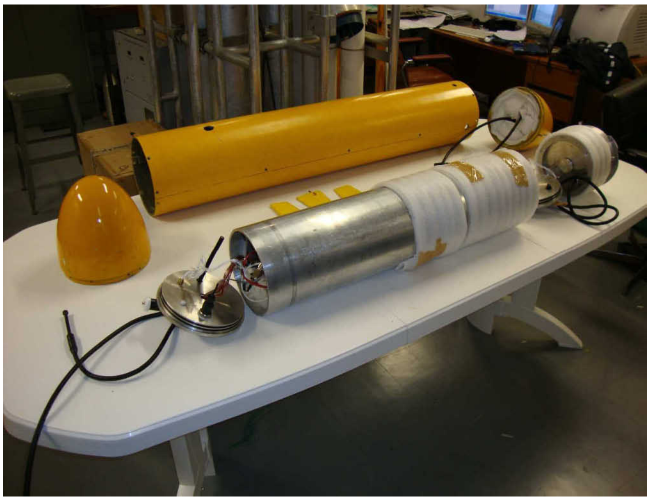

Figure 3. Parts of the hull, main e and manoeuvring vessels

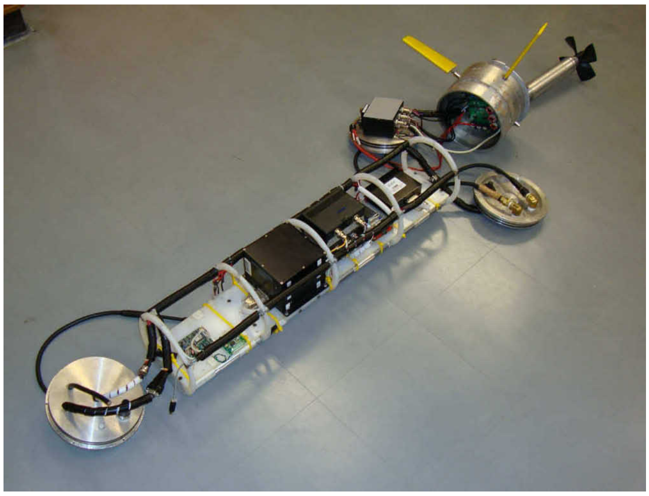

Figure 4. Main vessel electronics, manoeuvring vessel and thruster.

The vehicle is a free flooding type AUV, having an external hull made of fiber glass, and three aluminium made pressure vessels inside: main vessel, manoeuvring vessel and thruster (Figs. 3 and 5).