Design and Implementation of Hotfoot by UFRJ Nautilus.

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***Abstract*—Hotfoot is the first Autonomous Underwater Vehicle designed by the UFRJ Nautilus. A multi-disciplinary undergraduate team from Federal University of Rio de Janeiro came together three months ago in order to design and built an AUV for the RoboSub Competition. Due to the short time, the best strategy to follow has been to implement modifications and improvements in an existing ROV, available in University. The selected design is based on a PVC tube, containing all the electronic modules of the AUV, and sealed with o-rings, bound to an aluminum frame, and propelled by three thrusters, one vertical, beneath the hull, and two horizontals, placed one on each side, both for propelling and steering.**

I. INTRODUCTION

The Hotfoot has been designed and developed by students of Naval and Ocean Engineering, Electrical and Computer Engineering and Control and Automation Engineering, departments from Federal University of Rio de Janeiro. The vehicle is designed to navigate through the validation gate, to touch the buoy and navigation channel task.

This is UFRJ Nautilus' first year competing in the underwater competition, thus all design and system integration has been done from scratch. The budget for the vehicle was approximately 500 dollars; therefore, the vehicle fabrication and most of the peripheral devices were made in-house using resources available at UFRJ.

In order to better achieve the goals in a tight schedule and low budget, and taking into consideration the skills of the team members, it was decided that the best approach would be to divide the team into three sub-groups:

- Marketing, responsible for keeping track of deadlines, organizing the activities of the team, finding sponsors and being responsible for subscription issues
- Hydrodynamics and Mechanical, responsible for designing and building the hull, exoskeleton and auxiliary systems to secure the AUV would be waterproof
- Electrical, responsible for assembling the hardware and developing the software that will drive the AUV, as well as acquire and analyze data.

In comparison with the existing ROV, taken as the design starting point, mechanical design was improved in order to be more hydrodynamic. However, the design and selection of the electrical components were not influenced by the ROV. Major system design features including electrical infrastructure and mechanical design are presented.

A. *Mechanical*

Changes in mechanical design focus on the hull and its exoskeleton. The goal on changing these is to minimize the drag force acting on the Hotfoot. In order to achieve this, two domes were attached to both stern and bow. The exoskeleton was thought to sustain the modified hull with its motors and propellers, taking into account the need of making the wetted and frontal area also minimized.

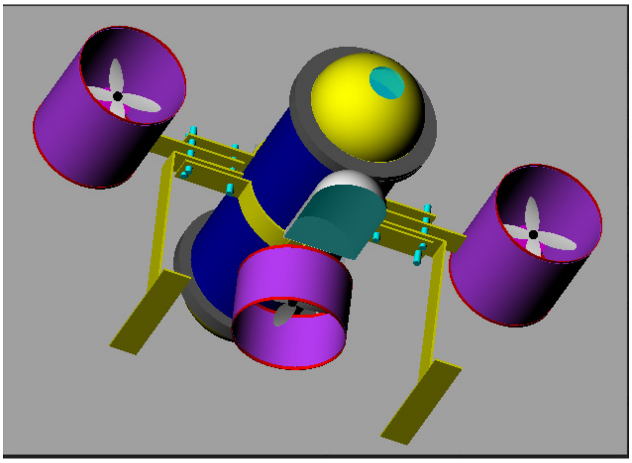

Figure 1: AUV'S mechanical design

Materials used for all the mechanical parts had to be the simplest and the lowest-cost ones. The hull is made of PVC pipe. Moreover, the two domes are 3D printed with ABS. The propellers' protectors are galvanized steel screens, so that the flow characteristics around these are not modified significantly. Finally, the exoskeleton is made by welding and folding carbon steel.

Three 320kv Turnigy Multistar Multi Rotor Motor working alongside three 2-blade ABS 3D printed propellers are arranged so that the Hotfoot is able to navigate in three basic degrees of freedom: surge, heave and sway.

In the AUV's design process, watertight is an attribute which must be thought carefully, otherwise all electronic devices may be lost. In order to ensure this condition, the Hotfoot design contains waterproof rings connecting the main body to the fore and aft domes. Furthermore, O-rings are used in each connection as second layers, avoiding the water entrance. In the hole in which wires pass by, silicone rubber was used to give a permanent seal.

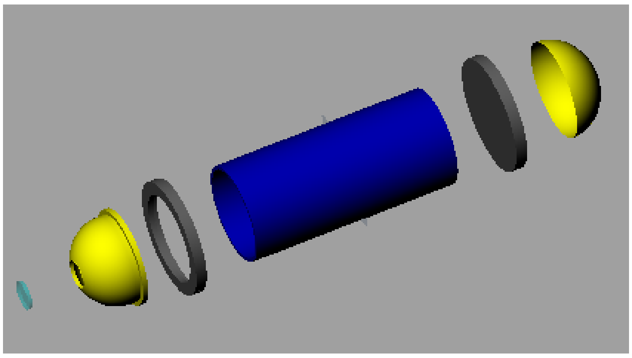

Figure 2: watertightness features

B. *Electrical*

1. Motherboard

The Hotfoot's motherboard was developed to perform as a raspberry shell and, at the same time, a source of its sensors. It consists of an ATmega-328P microcontroller with a USB-TTL converter which allows communication between the motherboard and Raspberry.

The motherboard has two security systems constantly acting, one of them to protect the microcontroller from overcurrent and possible surges and the other to disable the motors in case of emergency. For the protection system, keys activated by aligning magnetic field (reed-switch) alignment have been used. These keys are shifted ninety degrees geometrically. As the magnetic field applied to the system is always aligned with one of them, only one of the keys remain active while the other is turned off. When the switch is at position 1 the system is released for operation, while when it is at position 2 engines will be without power.

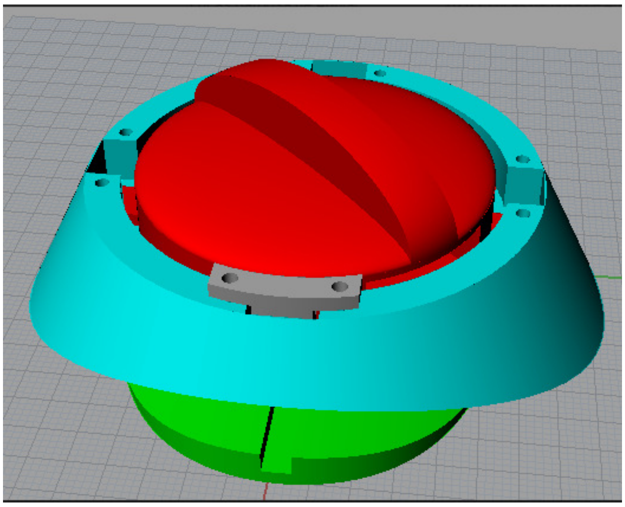

Figure 3: magnetic key

2. Computer System

As the team is starting, project and system were strongly influenced by three aspects: first the available material resources (e.g., battery, raspberry and camera), second the expertise of team members (e.g., several members had worked with Arduino) and finally the organic development of the team (i.e., most of the team's items were donated by members/advisor). Therefore, the start point was the simplest possible control system, a Raspberry Pi Model B + 512MB RAM along with an Arduino Uno - R3. Then, as already presented the Arduino was changed for the developed motherboard.

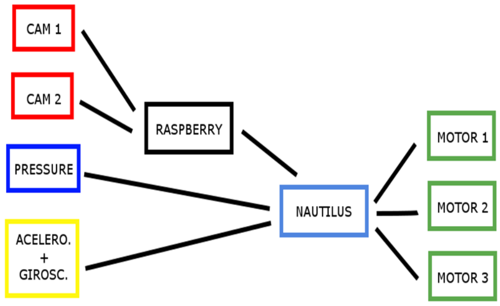

Figure 4: computational system organization

3. Battery

The battery was chosen considering three main aspects: expected working time duration, current discharge capacity and weight. The critical discharge current happens during the engine start. A 12 V battery 7AH is suitable for this case. Moreover, it is a lead-acid battery, which besides being reliable, its extra weight helps to balance the buoyancy and weight forces.

4. Pressure sensor

The AUV's navigation depends on some devices that provides AV's coordinates position. The pressure sensor is responsible to provide one of them, the vertical position. The onboard computer constantly reads depth information from the pressure sensor to make sure that the vehicle is in the right position.

The pressure sensor for Arduino has just three types of connection: positive (VCC), negative (GND) and the output (OUT). It requires 5 volts (DC) and can be used to measure the air or the water pressure.

5. Camera

The Hotfoot uses two Multilaser NigthVision web cameras. Each one can reach 16 megapixels, it has two lens made of glasses and LED lights, it uses a USB connection to transfer the video feed. The two cameras, one located at the front of the vehicle and the another one at the bottom, are responsible to make the AUV has a quite a few-degree field of view.

C. *Experimental Results*

Experimental tests on electrical components were performed to ensure that they are working properly. Circuit boards, magnetic key, motherboard and its connection to battery were all tested. Furthermore, the impermeability of the motors was also tested. However, until the present moment, the Hotfoot was not tested in a water tank; the ROV, on which Hotfoot is based, was tested for tightness. This test helped in achieving the best solution for impermeability of the hull.

D. References

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