Development of a Low Cost Autonomous Underwater Vehicle for Antarctic exploration

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The present work describes the design and construction of a Low Cost Autonomous Underwater Vehicle prototype for Antarctic Exploration to use it in the Ecuadorian Expedition to the Scientific Base Pedro Vicente Maldonado in Antarctica. This AUV, called HIPOPOTAMO III, can work as a platform to transport scientific payload in a determined path. The AUV length is 2m and diameter of 0.16m. Results of some systems of the AUV, from laboratory, sea trials and Antarctic environment are show. The vehicle has got four degrees of freedom: pitch, yaw, heave and surge. HIPOPOTAMO III uses a classical Torpedo architecture with small positive buoyancy. The vehicle achieves stable control with a set of three pairs of control surface. One pair is the rudder to control the yaw angle and the other pairs control the pitch angle. There are four sections in the vehicle, the propulsion module, batteries, scientific payload, electronics and digital camera compartment. The intrinsic buoyancy from the hull and nose cone is insufficient to make the vehicle float. Therefore is necessary to incorporate static buoyancy module to adjust the buoyancy. The buoyancy module uses disc-shaped of syntactic foam (density 580 kg/m3). In order to obtain stability in the water column when the vehicle is exposed to high underwater current, the buoyancy module is located at the top of the vehicle to maximize the distance between the center of mass and center of buoyancy. The Sensor Suite currently onboard the HIPOPOTAMO III is the minimum set of sensors necessary to complete the mission of transport the scientific payload in a determined path in open waters: accelerometers MEMSIC 2125, Gyros IDC 300, magnetic compass Hitachi HM55B and GPS Parallax Receiver Module. The software runs on a Cyclone II FPGA Starter Development Board. The modules are described in hardware description language VHDL. The software architecture was divided in three levels. The functions of the Low Level are data processing and generation of control signals. The Mid Level implements de Guidance, Navigation and Control System and the Upper Level implements the Mission Manager. The role of the guidance system is to determine the reference coordinates to where the vehicle has to go. For this application is used a fairly simple algorithm called "Line of Sight" that generates the reference in the Yaw angle. The navigation system's role is to estimate the velocity, position and orientation of an underwater robot with reference to its center of mass. HIPOPOTAMO III uses a GPS/INS navigation system, the information of both systems is fused by the Kalman filter. The Inertial Measurement Unit (IMU) is rigidly adjusted to the vehicle's hull. The IMU is constituted by tree MEMSIC 2125 accelerometers, two gyroscopes IDG 300 and a Compass HM55B. The first field test in an ocean environment was carry out in Ayangue, Ecuador, 1°58'55.22"S, 80°45'18.79"W. The purpose of the sea trials is test the GNC system. The GNC performed satisfactorily during the mission but the surface current caused the vehicle drifted off course slightly, the total drift over the 4500m mission was 330m or 7.33% mission length. During the Ecuadorian XIV Expedition to Antarctica 2009-2010 was carry out a test of the GNC system, special emphasis of the Inertial Navigation System using a Robotic Arm and an Unmanned Ground Vehicle. The INS initially was tested onboard the Chilean's Navy Icebreaker "Admiral Oscar Viel" during the Drake Passage heading to Antarctica, we compare the true heading of the vessel and the heading estimates by the INS and found a significant error. Inside the Scientific Base Pedro Vicente Maldonado, a Robotic Arm was used to calibrate the INS to work in Antarctic environment and then the GNC was debugged on an Antarctic Unmanned Ground Vehicle. The total UGV mission length was 2.5 km, with temperature of -25 ^{o}C, after 78 min of operation the error position of the INS was 19m. The results of the HIPOPOTAMO III's performance obtained in the pool and sea trials correlated well with preliminary observations and expectations. The result obtained in Antarctic environment predicts a good performance of the HIPOPOTAMO III's GNC in these challenge conditions.

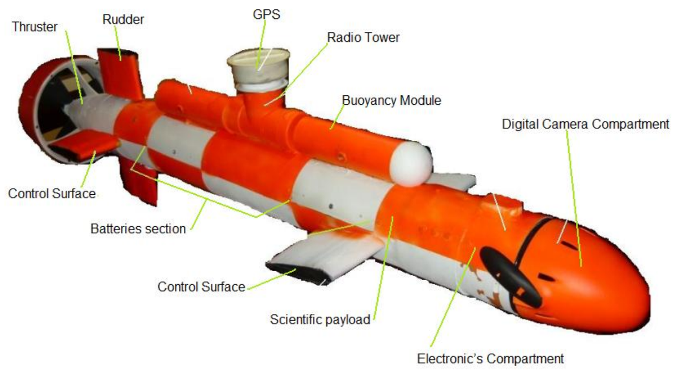

Fig. 1 Mechanical Layout of AUV HIPOPOTAMO

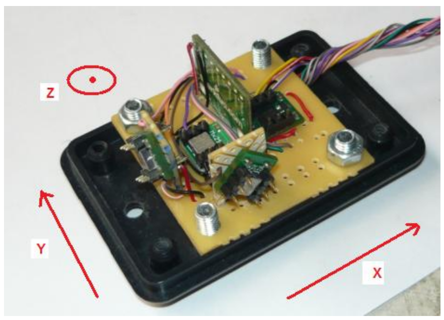

Fig. 2 Inertial Measurement Unit


Fig. 3 Test of the Guidance Navigation and Control System onboard the UGV in Antarctica near to the Scientific Base Pedro Vicente Maldonado.