Maritime State University AUV TEAM Autonomous underwater vehicle for RoboSUB 2016

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Abstract — Our team was founded in 2015 with the aim to improve students' skills in electronics, programming, mechanics and construction. MSU AUV team consists of a mechanic, two electronic engineers, three programmers and four advisors. Our vehicle was designed especially for the RoboSUB competition. MSU AUV sensor suite includes hand-made hydrophones, an Analog Devices IMU - ADIS16480, two color GiGE cameras by iDS imaging, a depth sensor. Our software was rewritten from scratch this year. We switched away from using Qt framework on our vehicle to Boost libraries. However, we are still using Qt for our GUI apps.

I. Introduction

The Maritime State University AUV Team was founded in 2015 with the aim to design and build autonomous underwater vehicles for the RoboSub Competition. Each team member is involved in one of the following areas: mechanics, electronics and programming.

Before constructing our vehicle, we searched for technical reports from previous years. After studying different teams practice in building such vehicles we developed our own requirements for our sub:

- The vehicle should be as light as possible, preferably less than 38kg. This would bring extra bonus points.
- The vehicle's structure should be modular. This allows us to replace battery easily and to have easy access to the electronics if it is necessary.
- To accomplish most missions, it is required to work with images. To process video successfully it is necessary to deploy high-quality machine vision cameras which will not break objects geometry and colors of images.
- An important requirement is easy maneuverability of the vehicle. To accomplish a number of tasks it is necessary to be capable of moving sideways. Also AUV should have strong stabilization system.
- One of the challenges for navigation system designers is reducing impact on the navigation units. We should reduce interference on our navigation as much as possible.
- Vehicle should be capable of operating in remote control mode. It will allow us to debug it easily.

II. Specification

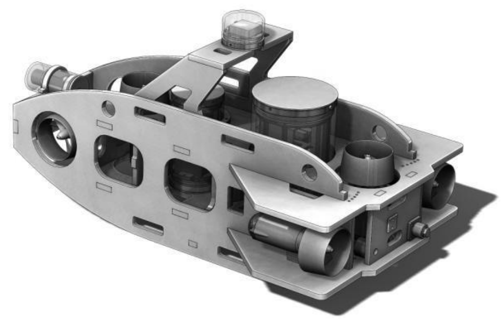

Fig 1. A SolidWorks render of MSU AUV

Table I

MSU AUV Specification

Mission/Vison computer	Intel NUC: Intel Core i5, 128 Gb SSD, 4 GB DDR3 RAM
Weight	36 Kg
Navigation controller	STM32F373
Hydroacoustic boards	Marsohod2, Custom amplification and filtering board
Hydrophones	Custom
Navigation	Analog Devices ADIS16480, Д0,1Т-4
Vision Sensors	2x GiGE cameras iDS UI-5260CP-C-HQ
Power Supply	25.9V 10Ah Li-Po
Connectors	РМГ, РМГД
Software	Boost (ASIO, MSM), Qt, Websocketpp, C++/Chai Script, Ubuntu 16.04

III. Mechanical Systems

A. *Frame and housings*

The vehicle's frame is made of polyethylene, which has neutral buoyancy. Our housings are acrylic and aluminum. The usage of these materials reduces need for additional buoyancy and helps to minimize apparatus weight. The battery is located in a separate housing and can be easily replaced by the charged one. It allows us to train without breaks for charging. There are magnetic compass and LED indication on the top of the vehicle. Such location of the compass reduces interference on it. LED shows status of apparatus.

The Vehicle consists of six housings: electronic acrylic housing, battery housing, front camera housing, bottom camera housing, IMU acrylic housing, and pressure sensor housing. Connections between units are made with transparent pneumatic cable.

We replace cameras' acrylic housings by aluminum in this year, because acrylic housings were damaged by pressure compensation system during previous RoboSub competition.

B. Thrusters

We use five thrusters to increase mobility, which is important for some missions. Two thrusters are used for moving forward or backward and yaw stabilization. One thruster is used for moving sideways and 2 vertical thrusters are used for surfacing or diving and vehicle stabilizing by depth.

Fig 2. Thruster

Thrusters are handmade. They are based on DC motors. Also, thrusters contain a built-in control unit. Thruster control unit is communicating with navigation controller via CAN Bus. Estimated thrusters thrust is 2 kgF.

IV. ELECTRICAL SYSTEM

A. Battery

AUV power supply based on 25.9V, 10Ah Li-Po battery. The battery's capacity is enough for 2-3 hours of the vehicle's work. Battery's switch is based on BTS555 high current power switch. The switch is controlled by an outer waterproof magnetic button. The kill switch is big and bright and located on top of the vehicle. That allows Sir. Diver to turn off AUV immediately. Required power supply voltage for all on-board devices and systems is converted by the power supply board, consisting of DC-DC converters and filters.

B. Computer system

We subdivide data processing between two computers: the main computer and the navigation controller. The main computer is Intel NUC based on Intel Core i5 processor with 4 gigabytes of random access memory and 128 gigabytes solid state drive. It is performing high-load data processing: missions planning and image processing. This computer has compact size and have enough performance to accomplish tasks allotted to it.

Fig 3. On board electronics inside housing.

The navigation controller is based on STM32F407 microcontroller. It is used for real time tasks: receiving and processing data from sensors, controlling magnets, controlling thrusters, calculating PID regulators, as well as monitoring the vehicle for leaks and other emergency subsystems. We choose STM32F407 for its good processing speed, energy-saving and peripherals, needed to handle sensors and thrusters.

C. Sensors

Cameras. We switched from using Allied Vision Tech Prosilica GC1380C cameras on our vehicle on to iDS UI-5260CP-C-HQ. Our new cameras have a wider angle of view and better color sensitivity.

Fig 4. Old and new cameras

Orientation sensors. The vehicle is equipped with IMU and the depth sensor. We use ADIS16480. It is a complete inertial system, that includes a triaxial gyroscope, a triaxial accelerometer, triaxial magnetometer, pressure sensor, and an extended Kalman filter (EKF) for dynamic orientation sensing. It makes it possible to determine roll, pitch, magnetic heading, and rate of angular motion of the vehicle.

Magnetic heading is subject to interferences generated by thrusters and electronic systems. In order to reduce their impact, we did our best to locate inertial system as far from the interference sources as possible and placed it on a separate housing on top of the vehicle.

Depth sensor. In order to determine the depth, we use piezoconverter Д0,1Т-4. We designed and built a separate board based on STM32F373. The depth sensor board is used for analog-to-digital conversion. All data from this board are transmitting via CAN Bus on to navigation controller.

Fig 5. Disassembled depth sensor

Due to the use of a separate controller with 16-bit Delta-Sigma analog-to-digital converter, and minimizing the length of wire between controller and piezoconverter, we receive the depth data with sufficiently high accuracy.

Hydrophone Array. Hydrophone system is needed for acoustic pinger detection. It is based on three hydrophones and signal processing board. Hydrophones are handmade. For better identification of the "ping" hydrophones are located at the bottom of the vehicle.

Signal processing boards are used for signal amplification, analog filtration, analog-to-digital converting of the signal, and mathematical processing. This year we switched from using board based on STM32 to Russian board Marsohod2 based on Altera Cyclone III FPGA. New hydroacoustic electronics and software allow us to separate sonar waves by frequencies.

D. Communication

For the purposes of device interaction and data transmission there are two networks deployed in the vehicle: Ethernet and CAN Bus. "Bandwidth-greedy" devices are connected into Ethernet (main computer, navigation controller, video cameras, Wi-Fi router). In remote control mode communication with a surface is also effected via Ethernet. Thrusters and sensors are connected via CAN Bus (navigation controller, thrusters, pressure sensor, LED indication).

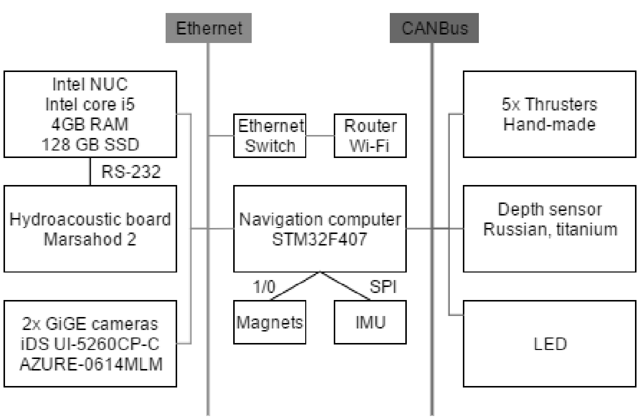

Fig 6. AUV networks

V. SOFTWARE

Our software was rewritten from scratch this year. We switched away from using Qt framework on our sub to Boost libraries. It's increased software performance and reduced memory footprint from 60 megs to 20. Also we designed new mission description subsystem, which based on Chai Script – scripting language. Also we redesigned our remote and debugging software. Now it's looks better and much more easy to use.

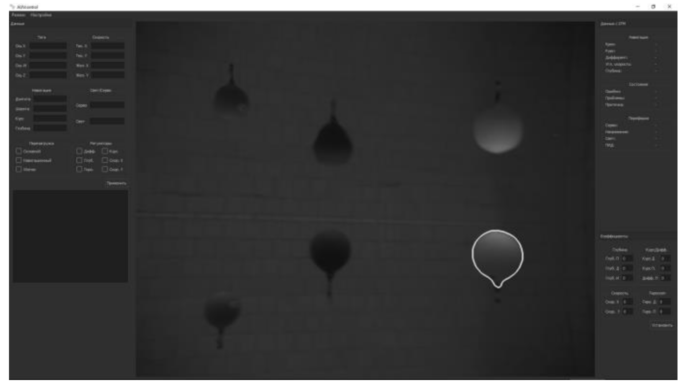

Fig 7. AUV debugging software (Yellow buoy detector running)

New mission description subsystem allows us to rewrite some part of the missions without recompilation. It reduces time needed for AUV debugging.

Our buoys, lines, gate detectors are based on binarization which was improved in this year. We designed new markers detectors based on Hu moments analysis.

VI. TESTS AND TRIALS

Vehicle functionality test is one of the most important stages in preparations for competitions which helps to identify unexpected errors in vehicle's hardware and software.

Fig 8. MSU AUV in the university pool.

While testing we checked the vehicle for being waterproof, ballasted and software have correct settings. It's an important feature of our vehicle that it is capable of operating in remote control mode which ensures easier getting the vehicle ready for missions.

VII. ACKNOWLEDGMENTS

Fig 9. Team photo.

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