Maritime State University AUV TEAM Autonomous underwater vehicle for RoboSUB 2017

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***Abstract* — MSU AUV team was founded in 2015 with the aim to improve students' skills in electronics, programming, mechanics, and construction. The team consists of two mechanic, two electronic engineers, three programmers, and three advisors. The vehicle was 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. The software was rewritten from scratch this year. The team switched away from using Qt framework on the vehicle to Boost libraries. However, Qt is still used for 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, to increase the level of students' professional skills, and the popularization of robotics in the Far East of Russia. In two past years, the team took prizes in the RoboSub competition. Thanks to this Maritime State University retains its position as the leading university in Russia on training of specialists in robotics.

At the beginning of the study year, the team recruits new members, so everyone in team has a different level of preparedness. Each team member is involved in one of the following areas: mechanics, electronics, and programming.

II. Design Strategy

Before constructing the vehicle, the team searched for technical reports from previous years. After studying different teams practice in building such vehicles MSU AUV Team developed requirements for their sub:

- The vehicle should be as light as possible, preferably less than 38kg. This would bring extra bonus points.
- The structure of vehicle should be modular. This allows 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. It is necessary to reduce interference on navigation as much as possible.
- Vehicle should be capable of operating in remote control mode. It will allow to debug it easily.

Fig 1. and Table 1 below show final rendering of the vehicle and specification.

Fig 1. A SolidWorks render of MSU AUV.

Table I

MSU AUV SPECIFICATION

Specification	Dimension
Mission/Vision 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	RMG, RMGD
Software	Boost (ASIO, MSM), Qt, Websocketpp, C++/Chai Script, Ubuntu 16.04

III. Mechanical Systems

A. Frame and housings

The frame of vehicle is made of polyethylene, which has neutral buoyancy. The 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 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.

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

B. Thrusters

Thruster Control Unit (TCU) is located with the electric motor in the thrusters housing. This solution allowed to save space in the autopilot and to save sensitive electronics of the vehicle from superfluous electrical interference. The team experience in the development of thrusters allowed to improve their design. In this year thrusters consist of two parts: the first part includes electromotor and TCU which are located together and the second part includes propeller with guide nozzle which is placed separately. The communication between the parts is realized by the magnetic coupling, not the shaft, as in previous years. This decision allows to make maintenance of thrusters easier and reduces the risk of penetration of water in it in many times, and, at the same time, to save the main characteristics of the thrusters that was previously.

MSU AUV team uses five thrusters (one of them is shown in Fig 2.) 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. Thruster control unit is communicating with navigation controller via CAN Bus. Estimated thrusters thrust is 2 kgF. The weight of each of them is 0.72 kg.

C. Torpedo launcher

The torpedo launcher, shown in Fig 3, is a construction consisting of a plastic tube with a torpedo inside of it, capacity of compressed air and solenoid valve which was installed between them. The solenoid valve is locked and keeps excessive pressure in the capacity before launch. When potential difference (voltage) is applied, it is opened and the air immediately with great speed goes through the tube, and simultaneously pushes the torpedo. An important element of the device is a tube, the length of which was chosen empirically taking into account the initial torpedo rate and its accuracy. Also the team paid much attention to the development and creation of the torpedo. Correct form and proper ballasting of it allowed to achieve the required results. Before each start it is necessary to make pumping and recharge device.

The team uses 2 torpedoes launchers. The weight of each of them is 0.8 kg, the shooting distance is 3 m.

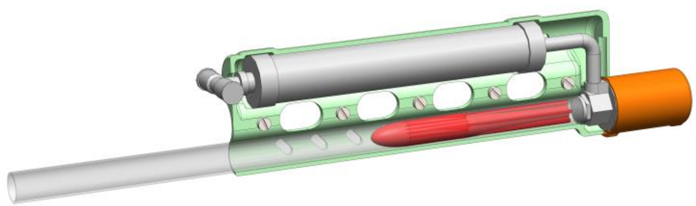

Fig 3. Render of torpedo launcher.

D. Marker Dropper

Marker Dropper, shown in Fig 4, is the device consisting of a plastic hollow cylinder and marker (a golf ball) which is located inside of it. *Latch*, which is placed in the lower inner part of the cylinder, fixes the marker. Due to the fact that the *latch* is pressed, marker does not fall out. Reset is carried out using an electromagnet, which controls the position of latch. When the electromagnet starts to work, it attracts the *latch* and ball falls out of the cylinder. The simplicity and reliability of the design prevents from unintentionally falling out of the marker.

The *MSU AUV* has 2 marker droppers with weight 0.25 kg.

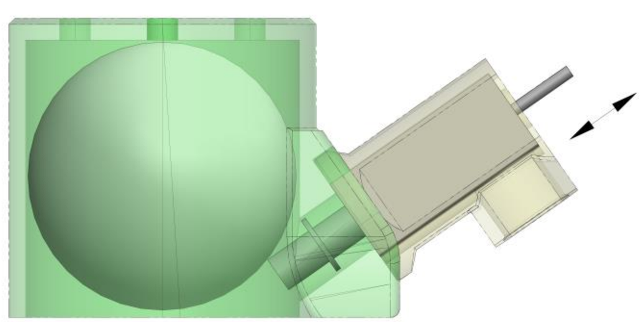

Fig 4. Render of marker dropper.

IV. Electrical System

A. Battery

AUV power supply based on 25.9V, 10Ah Li-Po battery. The capacity of battery 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

The team subdivides 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 has enough performance to accomplish tasks allotted to it.

Fig 5. 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. The team chooses STM32F407 for its good processing speed, energy-saving and peripherals, needed to handle sensors and thrusters.

C. Sensors

1. Cameras

MSU AUV team switched from using Allied Vision Tech Prosilica GC1380C cameras on the vehicle on to iDS UI-5260CP-C-HQ. New cameras, shown in Fig 6, have a wider angle of view and better color sensitivity.

Fig 6. Old and new cameras.

2. Orientation sensors.

The vehicle is equipped with IMU and the depth sensor. The team uses 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, the team did the 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.

3. Depth sensor

In order to determine the depth, the team uses piezoconverter Д0,1Т-4. MSU AUV team designed and built a separate board based on STM32F373. The depth sensor board, shown in Fig 7, is used l data from this board are transmitting via CAN Bus on to navigation controller.

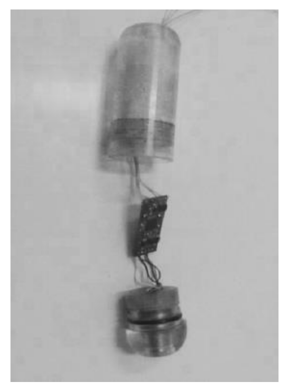

Fig 7. Disassembled depth sensor.

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, the team receives the depth data with sufficiently high accuracy.

4. *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 the team switched from using board based on STM32 to Russian board Marsohod2 based on Altera Cyclone III FPGA. New hydroacoustic electronics and software allow 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), as seen in Fig 8.

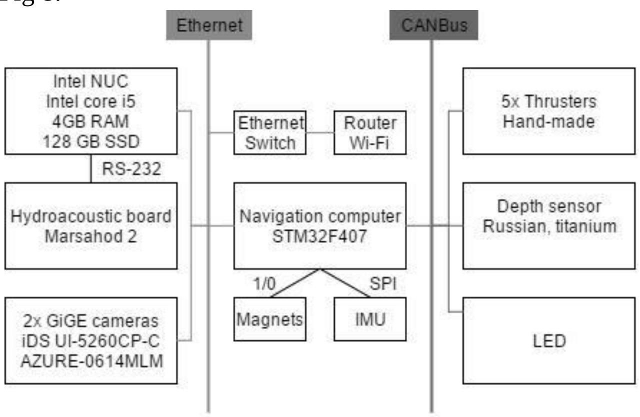

Fig 8. AUV networks.

V. SOFTWARE

The software was rewritten from scratch this year. The team switched away from using Qt framework on sub to Boost libraries. Thanks to this software performance was increased and memory footprint was reduced from 60 megs to 20. Also the team designed new mission description subsystem, which based on Chai Script – scripting language. Remote and debugging software, shown in Fig 9, was redesigned. Now it looks better and much more easy to use.

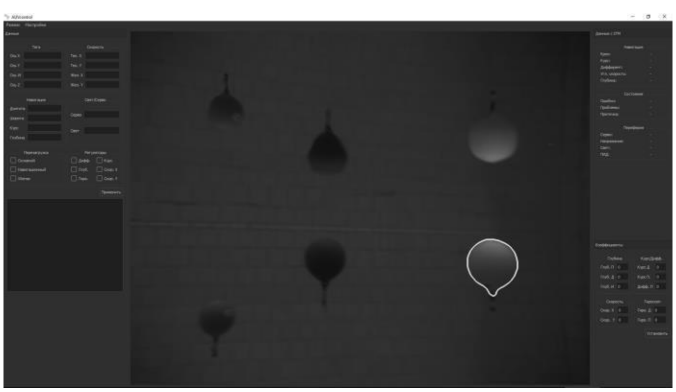

Fig 9. AUV debugging software (Yellow buoy detector running).

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

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

VI. EXPERIMENTAL RESULTS

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 10. *MSU AUV* in the university pool.

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

VII. ACKNOWLEDGMENTS

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