Maritime State University AUV TEAM
Autonomous underwater vehicle for RoboSub 2015

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Abstract

This is the first year the Maritime State University team participates in RoboSub 2015. We haven't got any experience in building autonomous underwater vehicles, however we have studied vehicles of other teams and have worded certain requirements to that of ours. On the basis of these requirements we have designed the vehicle. This resulted to be light, possessing easy maneuverability, equipped with specialized machine vision cameras, having modular structure, and capable. We decided not to attempt accomplishing all the competition tasks, but focus on some certain ones instead. At the current stage intensive vehicle debugging is taking place in a pool.

I. Introduction

MSU AUV TEAM is a team of the Maritime State University founded in 2015 for the purpose of building an autonomous underwater vehicle and participating in RoboSub 2015 competitions. The team comprises 8 team members and 3 advisors. Team members are sub-divided into three main groups: mechanical engineers, electronics engineers, and programmers. As programming seems to be most labor-consuming it is the programmers' group that is most numerous. The team captain is in charge of the teamwork management with facilitation on the part of advisors.

These are our first competitions of the kind and we haven't got any experience in building autonomous underwater vehicles. Therefore we previously scrutinized technical reports by ROBOSUB 2014 participating team, studied international practices in building such vehicles and developed our own requirements to the vehicle:

1) Vehicle should be as light as possible, preferably less than 38kg. This would bring extra bonus points.

2) Vehicle should be of modular structure. This allows for easy replacement of a down battery unit, or easy access to / replacement of the electronics unit, if necessary.

3) To accomplish most missions it is required to work with video images. To be a success in handling underwater video, it is necessary to deploy high-quality machine vision cameras, which will not distort geometric and color imaging and possess broad options for accommodation.

4) An important requirement is easy maneuverability of the vehicle. To accomplish a number of tasks it is necessary

to be capable of moving sideways and advancing turns.

5) One of the challenges for underwater vehicle designers is the impact of interference created by electronic systems and thrusters with magnetic compass. It is essential to minimize this impact.

6) Vehicle should be capable of operating in remote control mode. This will allow for easier debugging of the vehicle, making «benchmark» video shooting of mission props, monitoring mission progress in real time.

7) In our first year of participation in RoboSub we decided to refrain from accomplishing the tasks involving torpedo shooting. And to focus on the rest of the tasks instead.

Figure 1 – A SolidWorks rendering of MSU AUV TEAM's 2015 vehicle

Vehicle comprises six pressure hulls: main unit, battery, front chamber, bottom chamber, compass, and pressure sensor. Battery unit is a separate module easily detached and substituted with a new one.

Connections between units are made with transparent pneumatic lances.

II. Mechanical Systems

A. Frame and Pressure Hulls

Frame is made of polyethylene sheets 12mm thick. Hulls are made of acryl and aluminum. These materials feature sufficient strength at comparatively low density. This allows for minimizing the demand in additional buoyancy and making vehicle as light as possible.

B. Thrusters

To provide for easy maneuverability we use 5 thrusters: 2 thrusters have the duty of moving forward / backward and making advance turns, one thruster has the duty of moving sideways and 2 vertical thrusters have the duty of surfacing / diving and vehicle stabilizing as to pitch.

Figure 2 - Thruster

Thrusters are self-made. These are made on the basis of DC motors and contain a built-in control unit. Control commands are input via bus CAN. Estimated thrusters' thrust is 2 kgF.

C. Grabber

To accomplish tasks involving shifting objects and removing covers we designed a special grabber. This is located in the vehicle's bottom plane and represents a servo in a waterproof housing, which controls a hook bar. This hook is planned to be used for grabbing objects and removing covers.

III. Electrical Systems

A. Power Supply System

Vehicle is fed by Li-polymer BatteryPack, voltage of 25.9V and capacity of 10Ah. This battery can last for one hour of vehicle's intensive operation which is more than enough for accomplishing competition tasks.

Figure 3 – Battery modules

Battery switching on/off is controlled by electronic board on the basis of key BTS555. The key in its turned is controlled by an outer waterproof button. The button is big and bright, located on the vehicle's top, so that a diver in case of emergency can easily press it to disable the vehicle.

Power supply voltage for all on-board devices and systems is generated by the power supply board, consisting of DC-DC converters and filters.

B. Computer Systems

We distributed the functions of vehicle control among two computers: the main computer and the navigation one.

Figure 4 – Main unit with computers

The main computer is Intel NUC based on processor Intel Core i5. It is engaged in performing high-load duties: mission accomplishment planning and video image processing. This computer has compact size and satisfactory performance to accomplish tasks allotted to it.

The navigation computer is a board on the basis of microcontroller STM32F407. It is engaged in accomplishing tasks in real time: receiving and processing data from sensors, controlling operation units, computing controlling and stabilizing regulators, controlling thrusters, as well as monitoring the vehicle for leaks and other emergencies. Selection of STM32F407 is determined by its good processing speed, energy-saving and plentiful peripherals, needed to handle sensors and thrusters.

C. Sensors

Cameras

Two cameras Allied Vision Tech Prosilica GC1380C are installed on the vehicle. One camera is forward looking; the other one is downward looking.

These are specialized cameras intended for machine vision systems. They have high sensitivity, high definition, and make it possible to transfer video in real time via Gigabit Ethernet interface.

Orientation sensors

The vehicle is equipped with sensors for self-orientation in three dimensions and determining the depth in water.

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 platform on top of the vehicle.

In order to determine the depth we use piezoconverter Д 0,1T-4. For it we designed and built a separate board on basis of controller STM32F373, which digitizes the data, received from the piezoconverter, filters and converts them into depth readings. Piezoconverter and controller board are combined into one unit. The data from this unit are transmitted via network CAN.

Figure 5 – Disassembled depth sensor

Thanks to the use of a separate controller with 16-bit Delta-Sigma analog-to-digital converter, and minimizing the length of semiconductors with analog signal, going from piezoconverter to controller, we receive data on the depth with sufficiently high accuracy.

Hydrophone Array

Hydrophone system is intended for determining the direction of arrival of acoustic pinger. It is based on three hydrophones and signal processing board.

Hydrophones are custom-built. For better identifying direction of arrival hydrophones are located in extremes of the vehicle's horizontal plane.

Signal processing board is engaged in signal amplifying, analog filtration, digitizing the signal, and mathematical processing. From it the computed course – direction to the acoustic pinger and pinger type goes to the main computer. A feature of this board is digital potentiometers through which we can control signal amplifying factor in real time, which facilitates hydrophone adjustment.

D. Communication

For the purposes of device interaction and data transmission there are two networks deployed in the vehicle: Ethernet and CAN. Data-greedy devices are united into network Ethernet (main computer, navigation computer, video cameras, Wi-Fi access point). In remote control mode communication with surface button is also effected via Ethernet. Operation units and part of sensors interact via network CAN (navigation computer, thrusters, pressure sensor, LED indication).

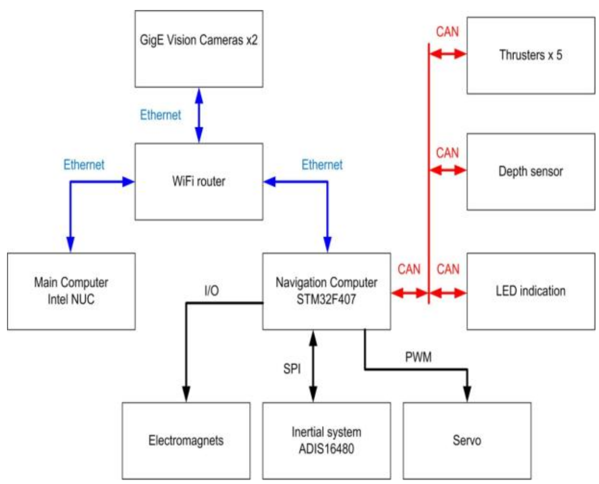

Figure 6 – Communication scheme

Additional devices can be easily wired to these networks, as necessary.

IV. Software

Our software was designed and made in compliance with the following principles:

- It should be as simple as possible without prejudice to functionality and expendability;
- It should be a cross-platform one, as team members use different operating systems and it would be ill mannered to make them quit their habitual environment.

Guided by these principals we chose as tools for implementation the following:

- OpenCV
- Qt/C++11

OpenCV contains a lot of image processing software algorithms and excellent documentation.

Computer programming language C++11 was chosen to secure maximum performance rating to our software.

Framework Qt contains a lot of useful things, which we used when writing software both for debugging, and for autonomous control system itself. Besides, it's a cross-platform one.

Our software consists of two parts: system of vehicle control from surface and autonomous control system.

The system of vehicle control from surface is a GUI add-up to the autonomous control system with a possibility for a trap to a gamepad. It allows us to monitor mission progress, view objects found.

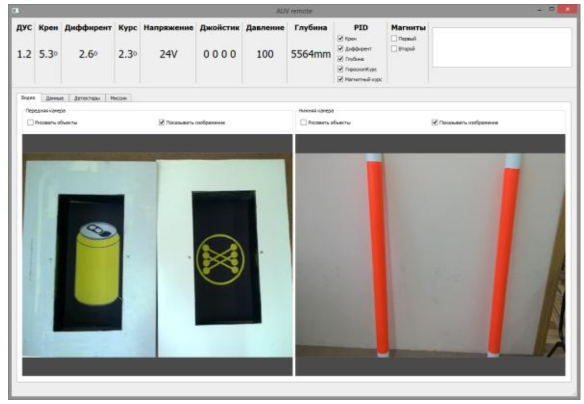

Figure 7 – Control Panel

We can add a detector for detecting objects during remote control by simple click-and-drag from one form to another.

This helps us easily identify under what conditions our detectors will not work and promptly correct the errors. The same can be done to missions.

Missions are described in C++ and represent a sequence of actions and conditional transfers, in dependence of objects found.

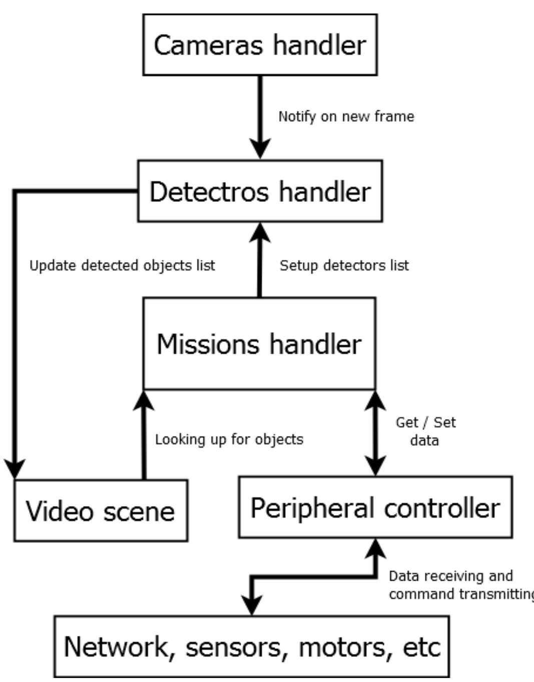

Figure 8 – Software Scheme

V. Tests and Trials

We started testing vehicles in a pool in the first half of June, in the University pool. Vehicle functionality test is one of the most important stages in preparations for competitions which helps identify unexpected errors in vehicle's hardware and software.

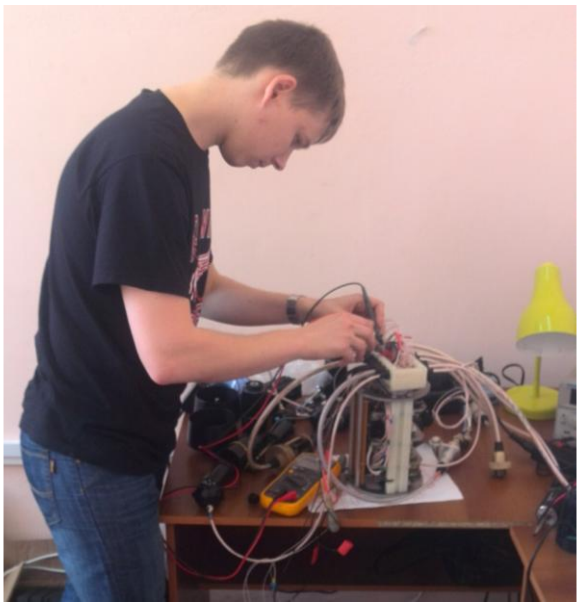

Figure 9 – AUV debugging

While testing we checked the vehicle for being waterproof, ballasted it, and selected suitable software 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. There's a chance to navigate through all the tasks, take pictures of these, and then when ashore to improve the software. Currently the debugging activities are still being continued and there's a lot of work ahead.

VI. Acknowledgments

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