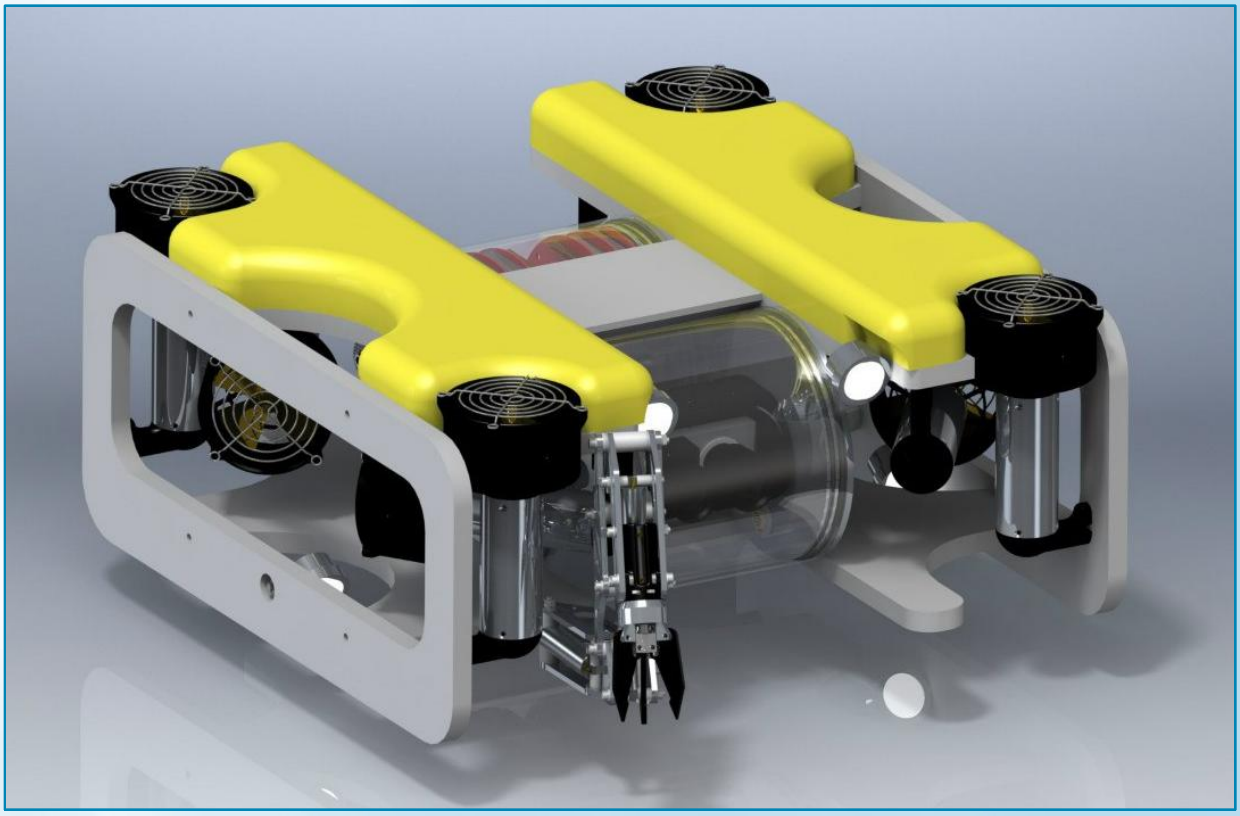
2012 MATE International ROV Competition

Bauman Moscow State Technical University, team "Hydronautisc ROV":

Akvator-3D

Explorer Class



Team mentor: Stanislav Severov – professor of BMSTU

Team captain: Ilya Kostandi, 5 course student

Team members:

Aleksey Semin – 4 course student, translator
Alexander Ryzhov – graduate, outsourcing consultant
Andrey Kozinov – 5 course student, manager
Assel Bushkova – 4 course student, PR manager
Denis Shipovskoy – 4 course student, experimenter
Dmitriy Kovalevich – 4 course student, investigator
Dmitriy Pastorov – 3 course student, engineer
Dmitry Garbuzov – graduate, technical report consultant
Ekaterina Lyamina - 5 course student, HR manager
Feliks Palta – 5 course student, program developer
Kirill Zyuzyaev – 5 course student, coordinator
Marat Minzaripov – 6 course student, designer
Margarita Korotkova – 4 cour. student, administrator
Natalia Petrova – 4 course student, technical support
Oksana Eroshenko - 4 cour. student, administrator
Pavel Ikomasov – 5 course student, risk manager
Stanislav Kozlov – graduate, consultant
Vadim Efarov – 3 course student, pool investigator
Valentin Myshkovsky – graduate, design consultant
Vladimir Kuznetsov –5 c. student, payload manager

Moscow, Russia, 2012

Abstract

It's the third time the BMSTU team is participating in the competitions MATEC. The backbone of the team is students of Underwater robots Department of BMSTU. This time the theme of the competition is associated with the pollution of water areas around the world.

During the World War II about 10.000 ships sank – this is about three-quarters of all diesel ships sunk in the history of mankind. Overall volume of oil in these ships is 20 times greater than the amount of oil spilled during Gulf of Mexico accident.

One of the current competition missions poses a problem of pumping out the oil from the fuel tank of the sunken ship. We have developed a special device for solving this problem. ROV provides access to the tank using manipulator, then attaches itself to the tank. After that operator activates a pumping oil mechanism.

Sunken ships have undergone a severe corrosion since the wrecking and represent a great threat to the global environment. Destroyed ship hulls must be extracted from the seabed. At the competition our team is required to locate metallic samples at the bottom of the pool. Akvator-3D (Fig. 1) is equipped with metal detector and can easily find these objects. For mapping the bottom, the vehicle must accurately determine its orientation in space. Our ROV has a compass which indications are displayed on the operator's screen. To determine the dimensions of the sunken ship hull Akvator-3D uses a tape measure with a special hook which attaches to the frame of wreck.

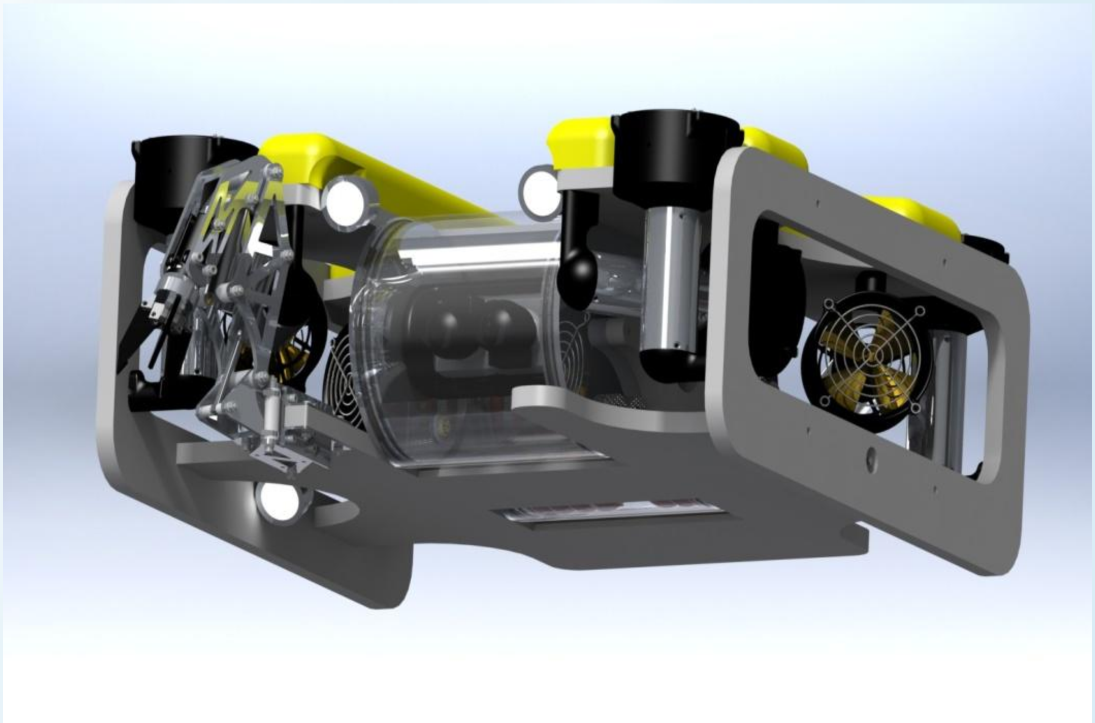


Fig.1 3D Model of Akvator 3D

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Budget/Expense sheet

Period: since 1.09.2012 till 20.06.2012
University: Bauman Moscow State Technical University
Mentor: Stanislav Severov
Funds: BMSTU; TETIS; RASIO; RISM; SCOLIPE; Students

№	Item	Quantity	Price per item, $	Total amount, $
1	Thrusters,based on MAXON 150 V	8	1016,1	8128,5
2	Camera box	1	794,3	794,3
3	Electronics housing	1	856,0	856,0
4	Digital video cameras	2	420,7	841,3
5	Rotatable camera box	1	769,7	769,7
6	Self-made signal and power cable for neutral buoyancy	30	7,1	213,0
7	Pressure sensor (strain sensor)	1	120,7	120,7
8	Orientation sensor VectorNav VN-100	1	717,7	717,7
9	Surface control system box	1	538,6	538,6
10	3-axial manipulator(frame)	1	166,7	166,7
11	Pneumatic cylinders for manipulator	8	28,2	225,3
12	Manipulator control box	2	615,4	1230,8
13	Manipulator's servo drive	4	68,5	274,1
14	Camera's and equipment servos	5	25,4	127,2
15	LED illuminators 20 W	4	28,4	113,6
16	Hardware platform Arduino	4	85,7	342,7
17	Electronics	1	287,4	287,4
18	Manufacturing pc boards	4	154,3	617,3
19	Secondary power supply unit	1	564,7	564,7
20	Buoyancy *	2	128,3	256,7
21	3D parts of equipment	1	1874,4	1874,4
22	ROV's frame(polypropylene)	1	204,3	204,3
23	Car monitor	1	416,7	416,7
24	120 Hz Display	1	789,7	789,7
	Total:			20471,3

*donation

Electrical schematic

The basic concepts of Akvator-3D "on board" circuit organization and pressure hull design are modular and interchangeability principles. Such solution allows us quick repair opportunities and gives us a chance for easy adding new board circuits in the pressure hull. Hence, future improvements and adding new tools wouldn't be as complicated as they were before.

Power unit (Fig. 2) contains two DC-DC converters (48V to 12V and 48V to 5V), which supply all ROV units with electrical energy. Total power consumption is limited by 2kW. That is why 40A safety fuse is used.

Propulsion system control circuit is based on 8 H-bridges formed by N-channel metal-oxide-semiconductor field effect transistors (MOSFET) IRFP4568. L6390 half-bridge gate drivers are used for controlling the H-bridge MOSFETs. STM Electronics recommends bootstrap circuitry to supply the high voltage section of the h-bridge. Using this circuitry has some disadvantages. The most important one for us is that bootstrap circuitry has limited duty-cycle (from 5% to 90%). We solved this problem by replacing the bootstrap circuitry and using TME1212 dc/dc converter instead.

Propulsion control system circuit is driven by 16 PWM signals. Components of the circuit were selected in such a way that power dissipation on them is low that means that the circuit doesn't heat up and doesn't influence stability of thermo sensitive chips. Also mounting heat radiators and developing cooling system are not required. Thruster control electric circuit diagram is presented in Figure 3.

Propulsion control system is represented by two boards - horizontal and vertical motion thruster's controllers. These boards are schematically identical, which makes them easier to produce and to replace failed ones "in the field". There are also two backup MOSFET half-bridges on each board to operate ROV lighting system. Besides, they allow us to complete a control system of the hydraulic manipulator with three degrees of freedom.

Akvator-3D control systems are based on Atmel microcontroller units. All MCUs are connected via I^2C bus. Communications block diagram is presented in Figure 4.

The electronics housing contains 4 boards at the moment: vertical and horizontal motion thrusters controllers, communication controller and pressure sensor processing board. DC-DC converters are also located on those boards.

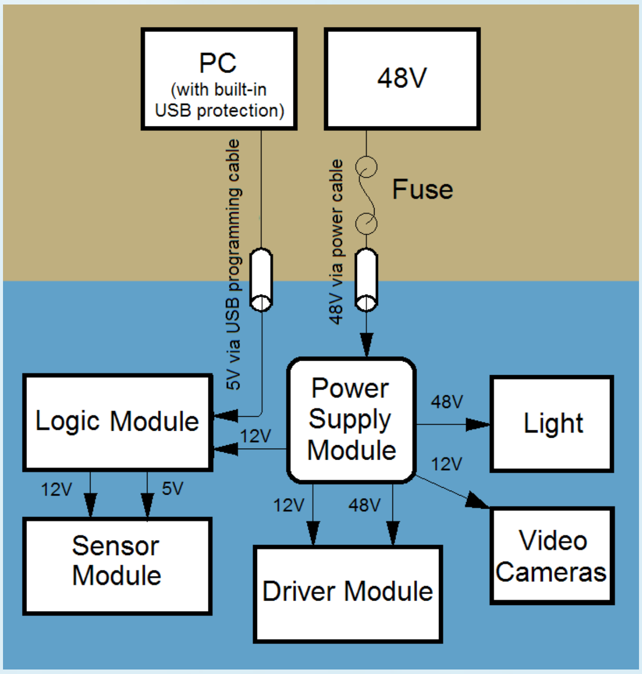

Fig. 2 Power supply circuit

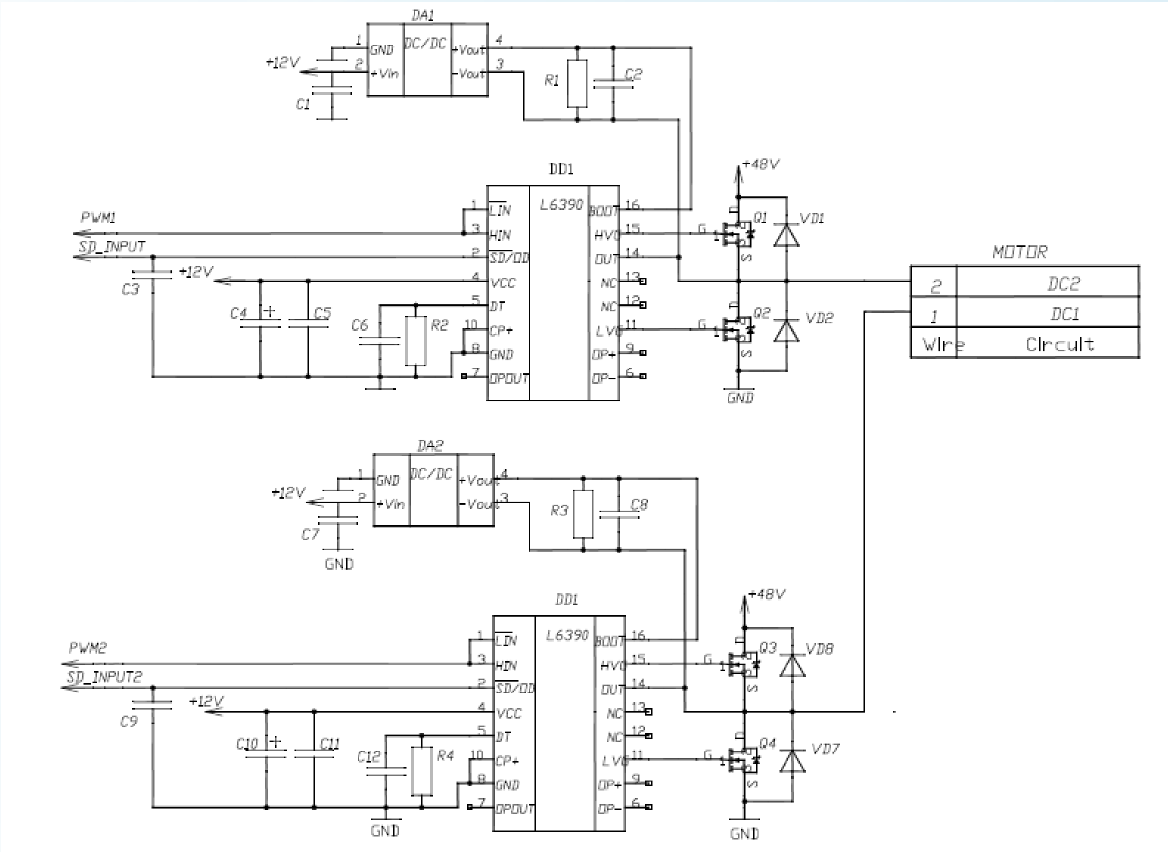

Fig. 3 Thruster control electric circuit diagram

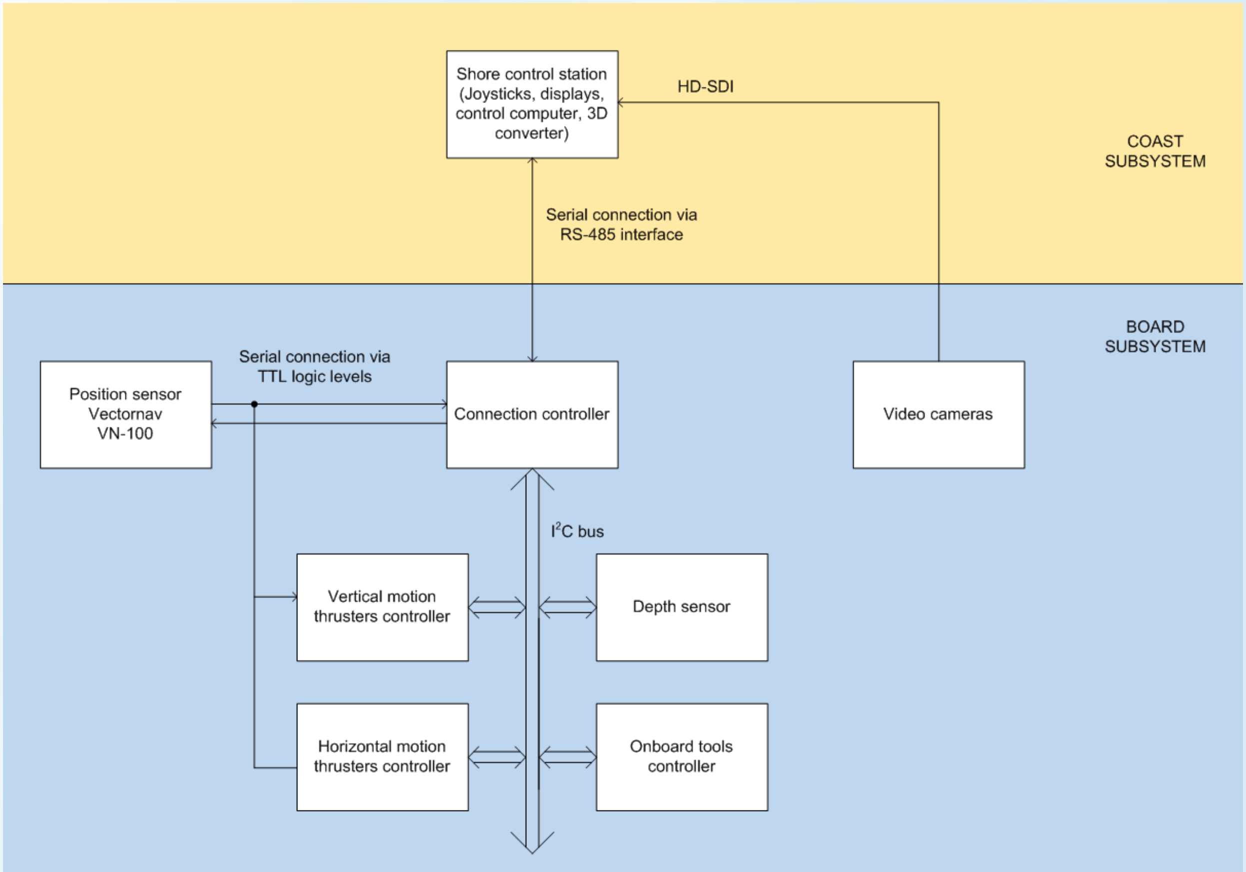

Fig. 4 Block diagram of communications

ROV control system features depth and yaw stabilisation systems. They use unique depth sensor designed by members of our team and Vectornav VN-100 orientation sensor. Our stabilization system can provide 1 cm depth accuracy and 1 degree yaw accuracy. The stabilization algorithm is presented on Figure 5.

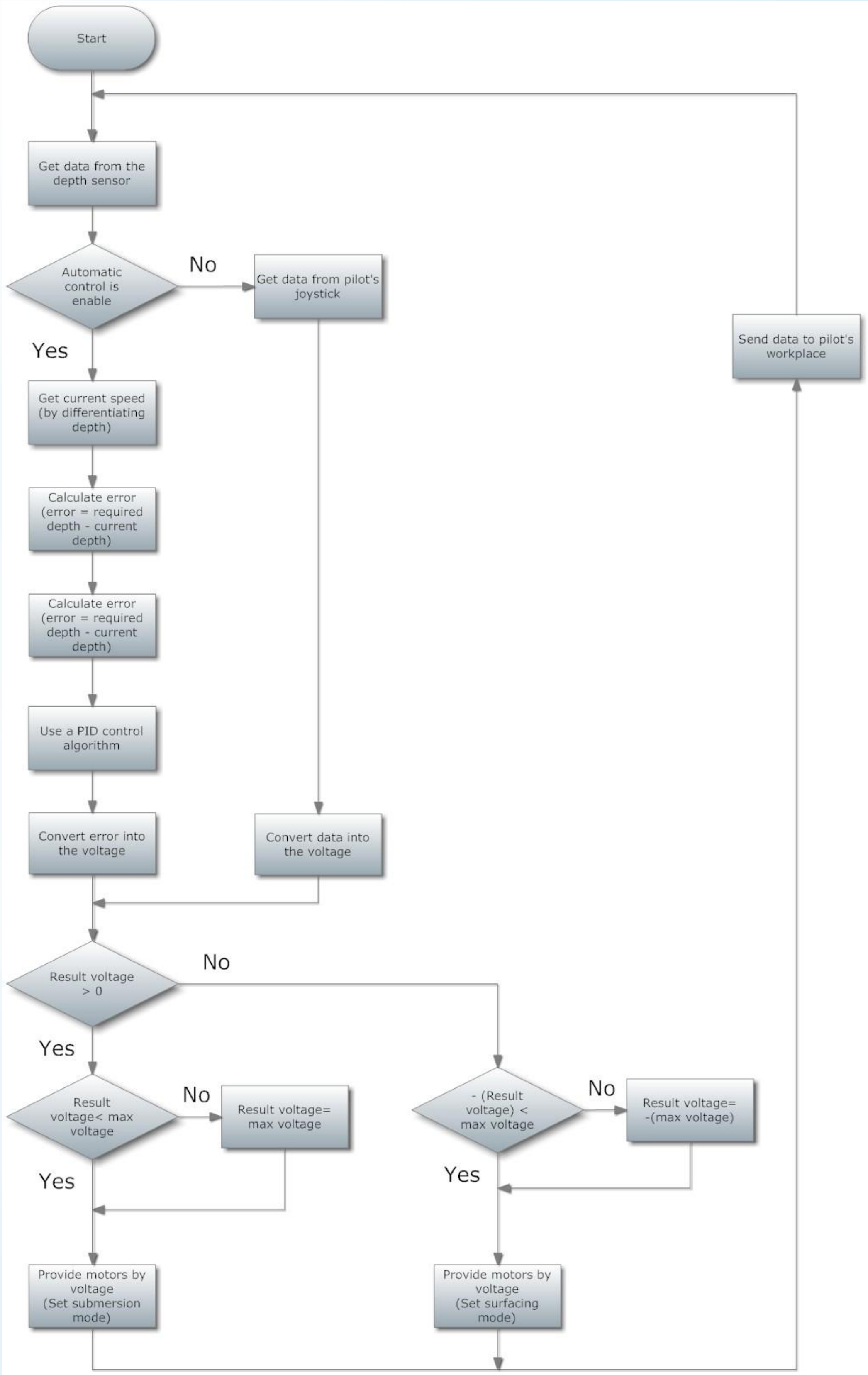

Fig. 5 Flow chart of stabilization system software

Design Rationale

Frame

The basis of all power and load-bearing structure of Aqvator-3D is a polypropylene frame. Thrusters, pressure hulls, buoyancy elements, weights and payload are all attached to the frame. This material was chosen because of its hardness, toughness and positive buoyancy. Plate frame material is better than PVC pipe. Tubular frame has a higher hydrodynamic resistance and added mass inertia than the plate frame. In addition, plate frame stabilizes ROV's motion in the longitudinal direction. Last year we used a frame of PVC pipe in the construction of ROV Akvator 2010 and saw it firsthand. Processing of the frame was performed according to the students' blueprints, using hydraulic cutting. It is worth mentioning that the frame was made only after 3D modeling (Solid Works environment) of the entire vehicle was completed. While installing equipment on the frame, the team strictly adhered to 3D-drawings.

Buoyancy

In conjunction with the other components buoyancy lighter elements, made of polypropylene foams, are mounted on the frame. Elements balance the vehicle using the residual buoyancy. They were pre-calculated in Solid Works environment. Their geometry and location were chosen for the baseline condition of neutral buoyancy of entire ROV and the absence of hydrostatic moments of heel and trim. Further on, we got the excess positive buoyancy of 20%, when the vehicle was in construction, up to 5-10% in working condition. Adjusting was carried out using balancing weights. As a result, Akvator-3D should have small positive buoyancy at any time, which provides emergency ascent, if propulsion system is crashed.

The pressure hull

The ROV, including pressure hulls, is designed according to the block-module principle. Akvator-3D consists of several waterproof hulls for different purposes. The electronics hull and the camera hull are of particular importance. They are the two biggest and most crucial hulls of the vehicle. They are made of a 180 mm cylindrical pipe that is shut from both sides by aluminum lids with hermetical lead-ins. The electronics hull contains the whole electronic part of the ROV's control system. It includes a connection controller, an active propelling control board complex, special devices controllers and others. Two Full HD video cameras are installed into the camera hull on a rotary mechanism. The fact that no bolts are used for the construction of the hulls is a distinctive feature. Radial rubber packing hoops that are located at the outer diameter of the hull covers provide hermetical adjoining of the covers to the plexiglass pipe.

In order to disassemble those pressure hulls the hull should only be pulled out from the special socket where the side covers are fixed by the elements of the frame. It is particularly useful during competitions when there is a lack of time.

There are several small pressure hulls in the structure of the ROV for the detached elements of the system that for some reason were taken out of the two main hulls. The orientation sensor unit is among them. The hull is a monolith part of an extremely complex shape. Students are able to build it in a short time because of the complex integrative usage of the computer 3D modeling and manufacturing, with the use of the same 3D model on a 3D printer. Thus, the hermetical orientation sensor hull consists of a base, where the sensing unit is located, and a cover that presses it down. The hull is special as it almost does not diminish the pressure effect on the hull of the sensor itself, but on the contrary is supported by the sensor. The only function of this hull is to ensure leak tightness. Nearly the same technical solution of the usage of the reliability of the sealed elements is prominent in other hermetical containers, particularly in a laser range-finder operator box.

Furthermore two hulls of the electric, mechanic and hydraulic transformation system are installed on the vehicle. The systems are a part of the manipulator control system. They are carefully inserted in the space between the camera hull and the electronics hull. The transformer hulls are complexly shaped and are also manufactured on a 3D printer.

All pressure hulls are designed for 1,5 MPa pressure that corresponds to 150 m depth. The calculations were performed in Solid Works package. The results meet the requirements. Underwater experiments and pressure, stiffness and leak tightness tests were conducted at 6 m depth after the assembling, which corresponds to the water levels of the competition pool. All pressure hulls were operating properly at this depth.

3D Vision System

People see the three dimensional world; it allows us to determine the distance to objects. However, this effect is not transmitted to the camera. Flat picture does not contain information of the mutual distance of the objects and it complicates the work of the pilot.

We equipped our vehicle with stereo vision system Full HD. This system (Fig. 6) consists of:

1) 2 digital Full HD cameras on board;

2) Surface module that combines images from the cameras and creates a frame-packing 3D HDMI;

3) Monitor, supporting NVIDIA 3D.

Fig. 6 3D Vision System

We can obtain three-dimensional image at small distances from the camera with this system. It is much easier to work with the manipulator and other devices and also it makes easier to operate ROV and navigate it in the space.

Propulsion system

By definition, ROV is an underwater movable object. The most difficult and responsible nodes of each ROV are thrusters. ROV performance, stabilization system characteristics, speed and propulsion of the robot depend on thrusters. Thus, they are the most expensive parts of the vehicle. In addition, thrusters must meet the requirements of MATEC and the aspects of the work in a fresh-water pool.

After analyzing last year's experience and a quota of 2000 W of electrical power, we decided to install four vertical and four horizontal thrusters according to the vector diagram. Based on the maximum of electric power for propulsion system we have developed specification for thrusters and completed it. The result of our semi-annual work is a propulsion system with the power of 150 W, based on collector motors MAXON. These thrusters (Fig. 7), meet all the requirements of MATEC competitions and are suitable for competition missions.

Sealing of the elongated shaft is carried out through a system of 2-reinforced cuffs (glands), which is structurally simple, and quite sufficient for the stated depths. Propulsion power in the mooring mode is 26 N. Grating, which is installed on both sides of the thrusters, eliminate the possibility of foreign objects falling into the propeller and make the unit safe even for children.

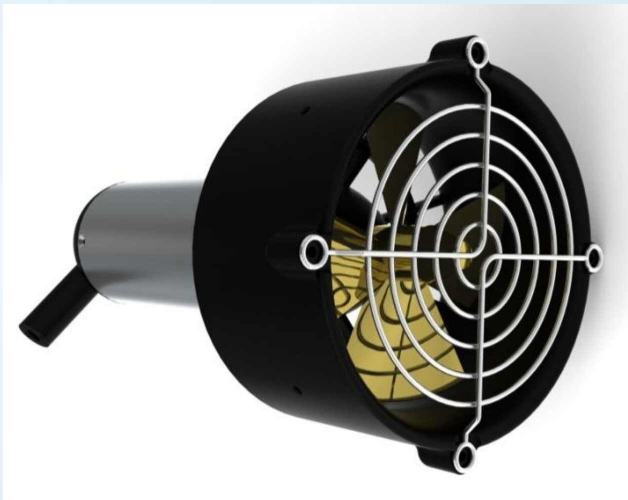

Fig. 7 Thruster

Orientation sensor

A well-known orientation sensor Vectornav VN-100 (Fig. 8) is used for the positioning of the vehicle in space. In the main mode (AHRS, attitude heading reference system) sensor provides three separate angle measurements, angular velocities and linear accelerations in all three axes. Measuring accuracy is provided by built-in Kalman filter. In addition, the gyrostabilizer mode (IMU, Inertial measurement unit) allows us to receive data directly from the accelerometers, magnetometers and gyroscopes sensors that we partly use.

VN-100 clock pulses set the frequency of the stabilization system loop. The sensor's update rate is as high as 200 Hz, which allows us to create a high-speed control system, including both depth and direction stabilization. The smooth spatial motion and accessible control system provides the ability to perform complex tasks of competition missions, which require high precision and maneuvering capabilities from ROV Akvator-3D.

Fig. 8 Orientation sensor

Control complex

To be able to quickly start operations in various conditions we have developed a mobile control station for our underwater vehicle (Fig. 9). It includes:

- impact-resistant container for the equipment
- 30-Inch widescreen display with support of 3D view technology
- joysticks to control ROV (the same are used in aircraft simulators)
- power units of 2 kW for the entire ROV
- the small-sized placard to display real-time readings from sensors
- converter to generate a stereo video sequence
- mini-computer to communicate peripheral devices with ROV.

Fig. 9 Control complex

Payload Description

Task #1: Survey the shipwreck site

Metal detector

To determine the type of sunken tanker's debris we decided to look into two devices: active sensor and flux-gate meter. The sensor (Fig. 10-a) allows quick locating of metal in the samples and saves a lot of time. However, the team faced difficulties, as sensor needed a shield and produced a lot of noise that interfered with the work of the device. The solution could be to carry out the sensor away from the vehicle at 40 cm, but this would make the design of our ROV too complicated. So the team developed and produced a simple flux-gate meter using a permanent magnet attached to a flexible tube (Fig. 10-b).

a)

b)

Fig. 10 Metal detector a) – active, b) - passive

Rangefinder

One of the competition's missions is to measure the length of the sunken ship. In order to do this, our team looked into several distance measuring methods: acoustic, geometric, kinematic, laser, and mechanical. After a thorough research, we developed and tested two different devices:

1)Laser rangefinder

2)Roulette with a flexible metal tape (Fig. 11)

Laser Rangefinder was sealed in polymeric container. Plate of silica glass was inserted into the lens. This device can make measurements up to 6 m, which satisfies the requirements of the competitions mission in 2012. Also we constructed a graph, with the help of which a conversion factor for underwater measurements can be found.

There is a particular issue in the measuring speed of a laser rangefinder underwater. If the distance is close to maximum (6 m), the delay is about 5 seconds. This implies higher demands for stabilization and positioning system. As a result, roulette was chosen, mainly, because it can measure the distance faster. However, laser rangefinder can be used as an alternative tool for measuring the length of the sunken ship and various distances.

a)

b)

Fig. 11 Range finders: a) – laser rangefinder, b)- roulette with a flexible metal tape

Depth sensor

Depth sensor is based on strain gauge pressure transducer (Fig. 12) Maximum allowable pressure is 15 PSI, which corresponds to the immersion depth of 10m. Electrical schematic diagram (Fig. 13) shows the scheme of the sensor power supply, as well as scaling and filtering of the output signal, developed by students.

As you can see, 14-bit analog-digital converter is used in this scheme. The microcontroller Atmel recieves the data, where it undergoes additional software filtering. Accuracy of the depth measurement is 1 cm.

The desirability and necessity of a functional depth sensor in the payload seems obvious. If necessary, we are prepared to explain our decision to install the depth sensor at the engineering evaluation.

Fig. 12 strain gauge pressure transducer

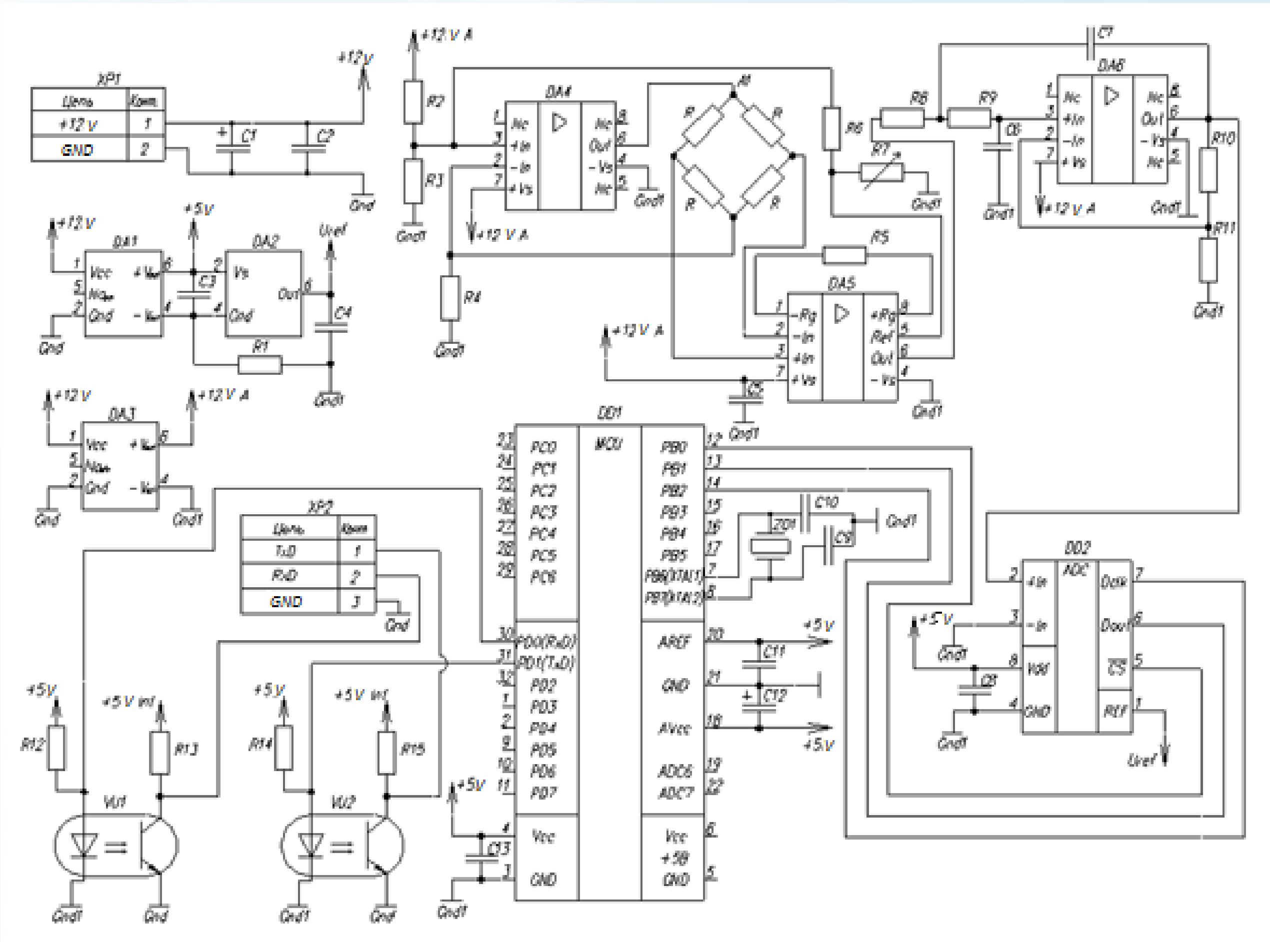

Fig. 13 Depth sensor electrical schematic diagram

Compass

For operator's convenience magnetic compass is included in the vehicle's payload. A different type of compass is combined with the orientation sensor. These decisions are made to ensure the reliability of determining the orientation of the wreck and location of objects on the site of the shipwreck. In the event of unexpected failure and crash of both onboard sensors due to the influence of magnetic field of the steel reinforcement of the pool's building, the vehicle is equipped with portable professional compass. This device could be used on a prelaunch training. We tested the device in the diving pool in Russian State University of Physical Education in Moscow.

We are informed that EXPLORER class teams must define the orientation from the stern toward the bow of the ship. The BMSTU team will be able to use master compass or a designated north/south line to calibrate their own compass or sensors.

Task #2: Removing fuel oil from the shipwreck

Manipulator

Most multifunctional element of construction of Akvator 3D is three dimension manipulator (Fig. 14). Manipulator is used for positioning a thickness sensor and labeled neutrons sensor.

Manipulator could be used for transplantation coral models, moving mast, penetration to the fuel tank ports and other operations. Design of the manipulator is based on pneumatic cylinders witch commonly used in airplane models for nomination of the chassis. We applied aerospace technology to the underwater robotic design. Every wetted cylinder is set in motion by another cylinder (we can call it main cylinder) which is located in the dry pressure hull of ROV. Main cylinder is connected with powerful servo mechanism.

Manipulator was designed as a multifunctional device for various missions. It can interact with all attachments of the ROV. Every new task require adaptation of executive body's parts and microprocessors'

Fig. 14 Manipulator

Lift Bag

Hydrostatic uplift of the lift bag is created and regulated by the volume of the fluid, which is forced by the airbag, placed in it. Lift bag design is presented in the form of a soft elastic airtight shell, placed in a sturdy loose-fitting grid. The elastic shell has a nipple with back valve for pumping and draining air. The underwater cargo should be attached by the grid. Pumping is performed with the use of airlift pump, which is used in the removal of oil from the tanker. The proposed construction of the lift bag is technologically simple and easy to manufacture. It does not require the use of expensive materials and equipment. You can find more information about Lift bag in "Engineering Evaluation" part.

It is known, that MATE Center, with the support from SUBSALVE USA (www.subsalve.com), will provide 25 pound lift bag to any EXPLORER class company. Alternatively companies are free to engineer or purchase its own lift bags. The weight of the EXPLORER class mast is between 50 and 75 Newton (in water). BMSTU team will be able to use its own lift bag, as well as a lift bag provided by MATEC.

Oil extractor

For the removal the oil from the tanker and its replacement with the salt water, we are using a special device (Fig. 15). It consists of two fairly solid, but flexible polymer extractor tubes directed vertically downward. It also has conical hopper-catchers and inflatable torus elastic elements fitting the free ends of the tubes.

At first, hopper-catchers are used. They make it easy to align the extractor tube in the holes. Further, a solid plastic tip tube acts as a drill, penetrating through the plugging layer of petroleum jelly. When the pilot decides that the drilling is completed, and the tubes are immersed in the hole deep enough, rubber bags, which are slightly above the tip, are filled with the air. All above mentioned elements create an interconnected system, which consists of a tank vessel, inlet and outlet pipes going along the ROV's cable, and the tank on the surface. The surface tank has a movable partition, and is initially filled with the salt water. When the partition is set in motion, the salt water begins to fill the tube leading into the outflow port. At the same time, low pressure zone is formed in another tank cavity, thus starting the pumping of the oil. Rubber bags' inflating mechanism is also located on the surface and consists of a syringe with air.

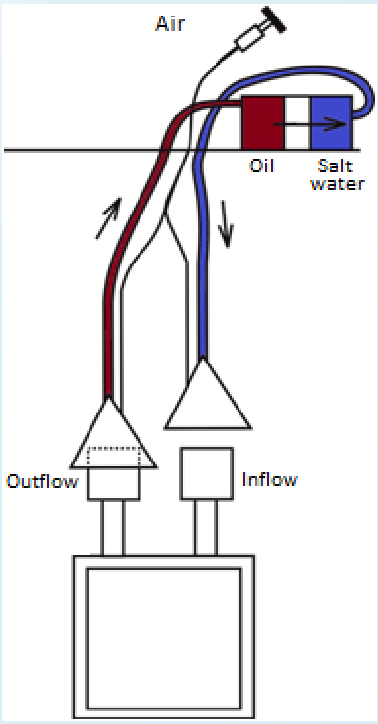

Fig. 15 Oil extractor

Troubleshooting techniques

During the testing process our team faced with the problem: while ROV was in the water - we often lost the signal, so that it became impossible to use microcontroller and take data from the sensors.

We realized that this was happening because the connection between test connector and the “broaching cable” (which was wrapped in scotch tape) was not sealed properly. When the water flowed into the wire, we lost the communication channel.

At first it was proposed to buy a special sealed connectors, but due to their high cost, dimensions, and complexity of the acquisition, the idea was rejected.

After that we tried another way to solve the problem. Our connecting cables were covered with the special adhesive tape. But this only reduced the number of faults, and besides this worked only when the vehicle was underwater for brief periods of time. When diving was long, the problem surfaced again.

With each dive, the probability to see stable readings decreased. First, there were interruptions in the reception of sensor data management system. Then the data was available only when the thrusters were turned off, and soon it became impossible to get any valuable information.

We decided that the problem was a bad soldering of wires, or they were damaged. After a brief inspection of the cable, it became clear that the veins were oxidized and blackened along the entire length, and leaving the wire in such condition was not an option. Therefore, a faulty cable was lowered into a specially made container with acid for soldering and remained there until complete dissolution of the oxide film.

During this time, the team found a workaround. We made "quick connector“ (Fig. 16), which allowed only a single flash of the microcontroller (the main cable allowed to reprogram everything, because it contained several USB connectors.) It could be used only on the shore, but this provided an opportunity to visually evaluate the efficiency of system.

We had to restore the main cable, and therefore, after drying, the test connector was completely revised and redesigned. This time we used a slightly different design for better sealing, thus decreasing the probability of water intrusion. The overall length of the wire was increased, which gave the team the possibility to distance power supply, electronics and laptop from the side of the pool.

Fig. 16 "Quick Connector" and the final version of the basic socket.

Challenges

This year there have been many technical problems. One of the competition tasks was the identification of metallic and nonmetallic debris on the site of the shipwreck. We've boldly imagined ourselves as entrepreneurs of a virtual trading company UWIS-Underwater innovation systems. For metal detection tasks, we decided to develop a portable metal detector (Minelab type). We generally designed a retractable system, thought out its sealing, began to study the processing of signals, but then encountered a strong induction of the interference from the vehicle to metal detector and vice versa. We also underestimate the problem of limited space for the installation such voluminous device as metal detector.

We had to put in place a simpler fluxgate device. Its capacity is sufficient for performing competitive tasks and to determine the nature of debris.

The non-technical challenge that arose before the team was an effective communication with foreign colleagues. Last year we lost some points in the competition because of the lack of expertise in translating technical documents. The mentor of the team, Stanislav Severov, identified five students, who took English courses to improve their knowledge of technical English. The BMSTU team also used the "Underwater Robotics: Science, Design & Fabrication" book, written by Dr . Steven W. Moore, Harry Bohm, and Vickie Jensen." This book was indispensable in getting acquainted with the correct terminology in the field of underwater robotics. We are thankful to its authors.

Future Improvement

Our team reviewed a number of decisions taken in the design of the ROV's devices this year, and made appropriate conclusions.

We realized that electronics case should be placed vertically thus leaving free space for special equipment. In our present ROV, electronics case is positioned horizontally. It takes a lot of space on the bottom of the frame and creates difficulties for the placement of devices.

In the future we plan to make a symmetrical design, i.e. cameras, lights and devices will be located on both front and rear of ROV. The cameras will be placed in separate sealed cases, as it is done on the industrial ROVs.

We also plan to remove the servo machines, used in manipulator system, and build a complete hydraulic system.

Lessons Learned

Creating our own electronic circuit boards has given us a useful experience this year, but the most importantly we have managed to design original thrusters.

Our programmers have studied and successfully applied new communication interfaces, such as I2C, SPI, RS485. They are used to establish a connection between the vehicle and peripheral devices.

We have developed control and stabilization system, which allows the vehicle to keep a certain depth and angle of the course, as well as to compensate for external disturbances. Now the ROV has become much easier to operate.

Reflections

Participation in the MATE International ROV Competition-2012 is a great opportunity for all BMSTU team members: both experienced and new. We are grateful to MATEC for the chance to get experience in the development of a real underwater vehicle, and extend the boundaries of our competence. This is practical application of all knowledge that we receive during studies. It is marvelous that MATE competition provide an opportunity to test ourselves in different areas of engineering: electronics, programming, design, modeling, and project management. Many of the active project’s participants experienced an increase in academic performance.

This year's BMSTU team includes mostly new members. All mistakes of the previous teams were taken into account, and after having gone through this “school of trial and error”, we’ve decided to radically change attitude towards the team work in the project.

Teamwork

Project "Akvator-3D" involves a lot of tasks in different directions of the project activity: organization, planning, design, supply, manufacturing, research, testing, etc. To manage such a large number of different tasks and operations a clear division of labor and responsibilities is needed. Gantt chart was used to schedule tasks by priority and deadline. We put all the work associated with the implementation of the project in the chart and assigned responsibilities.

Stanislav Severov, the team mentor, provided educational support to the team.

Pavel Ikomasov, the risk manager, designed software for stabilization the depth and route systems and wrote “Troubleshooting Techniques” part of technical report.

Vadim Efarov, the pool investigator and engineer, and Dmitriy Pastorov, engineer, designed and created a control complex of Akvator-3D and wrote instructional documentation for it.

Ekaterina Lyamina, the electronics engineer and HR manager, designed and created PCB of engine control driver, prepared documentation on vehicle’s electronics for technical report, and organized regular team meetings.

Felix Palta, the program developer and electronics engineer, designed and implemented an onboard intercontroller communication using different interfaces; he also created a functional and electrical circuit's link.

Vladimir Kuznetsov, the payload manager, developed onshore software and communication link with the shore systems, and described the work of the hydrostatic pressure sensor for the technical report.

Ilya Kostandi, the team captain and the main engineer of the vehicle, participaed in the development of the multiple ROV systems and edited the "Design Rationale" part.

Dmitriy Kovalevich, the investigator, and Denis Shipovskoy, experimenter developed a laser rangefinder for the ROV and a documentation for it.

Natalia Petrova, the engineer and member of technical consultant, designed the stand for propulsion system measurements. She was in charge of creating test bottom equipment (20 units).

Assel Bushkova, the PR manager, wrote and posted a series of press releases about team's participation in MATEC competitions-2012 in Orlando.

Valentin Myshkovskiy, the design consultant, provided consultations for programming on-board analog devices of ROV's payload.

Alexander Ryzhov, the outsourcing consultant, provided consultations the development of the tools and devices of the manipulation complex.

Stanislav Kozlov, the consultant, organized the team work and took part in creating of the core product of the project-ROV «Akvator 3D».

Dmitriy Garbuzov, the technical report consultant, participated in the testing of the analog devices of the prototype vehicles.

Marat Minzaripov, the designer, created the outer design of the vehicle and created the Poster for the MATE competition.

Alexey Syomin, the translator, took part in translating entire documentation part.

Andrey Kozinov, the manager, collected, analyzed, and _ edited information for the Poster.

Kirill Zyuzyaev, the coordinator, was responsible for collecting and editing materials for the Technical Report.

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