Maritime State University named after admiral G.I. Nevelskoy Technical Design Report underwater vehicle: Ivan! 2022

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I. Abstract

The MSUR team has completed the development and improved our last year's underwater autonomous vehicle "Ivan!". The basic design of the device has not changed and consists of two modules: the main module with electronics, navigation system and engines and a removable payload module that can be quickly and safely replaced to perform various tasks, such a complex solution allowed us to have greater flexibility to use the AUV, as well as ease of transportation

Our updated platform has better software and hardware than last year. The new platform has more flexibility, reliability and uses advanced industry standards such as embedded systems and ROS2

II. Competition Strategy

Due to the limitations associated with the coronavirus, which affected the fact that we could not work in the laboratory all together and it was necessary to plan the loading of the room in such a way that the minimum possible number of people would be at the same time, in addition, we have not been able to participate in face-to-face competitions for the last two years. The composition of our team has been almost completely updated and we lack practical experience in using our AUV. Also, former members of our team gave us advice that not only the technical capabilities of the AUV are important, but also a good strategy for completing tasks. Therefore, we decided to focus only on performing the part of the tasks in which we are most confident and for which we had enough time and experience to work out: passing through the gate, navigating by way signs, touching buoys and surfacing inside the octagon Appendix B.

A. With Moxy—Coin Flip

To successfully pass through the gate, we orient the device perpendicular to the gate, then according to the rules, the device dives to a given depth and begins to move, focusing on the silhouette of the gate and passes through them

B. Choose Your Side—Gate

To successfully pass through the gate, we orient the device perpendicular to the gate, then, according to the rules, the device dives to a predetermined depth and starts moving, focusing on the silhouette of the gate and passes through them, after losing the g-men image from the field of view, we mark the timer for 5 seconds, this will allow us to pass through the gate and after that we moving on to the next task

C. Path and Make the Grade-Buoys

After passing the gate, we use the camera pointing to the bottom to look for a path marker, after finding it, we orient the device to the larger side of the parallelepiped describing the path marker and with the camera pointing forward, we look for the Tommy Gun image in accordance with our G-Men role, after finding the marker, we head to the Tommy Gun image until we lose the image is out of sight and then we move for another 5 seconds

D. Collecting—Bins

After finding the path marker, we move to the next task and use the lower camera to

look for images in order to orient the device and reset the marker using the marker reset device, which was presented in detail last year

E. Survive the Shootout— Torpedoes

After passing the buoy, we look for the direction vector to the buoy closest to us, focusing on the signal power, after finding the vector, we start moving and look for the Bootlegger marker in parallel, after finding it, we approach to such an extent that the marker occupies 80% of the frame height, after that we aim at a larger distance and make a shot, after finishing the shot we again we are looking for an acoustic beacon, but now a remote one

F. Cash or Smash—Octagon

Starting to move to the lighthouse, we set A To a depth of 1 meter and look for a bottle marker, after detecting the marker, we center and float to the surface in the octagon

III. Design Creativity

There is a clear division in our team into the following roles: designer, programmer of upper and lower level, electronics engineer. The student takes a role depending on the competencies he has. Students are guided by mentors who control the process of building the AUV, give advice on any questions that a student may have, and take part in the coordination of the entire project.
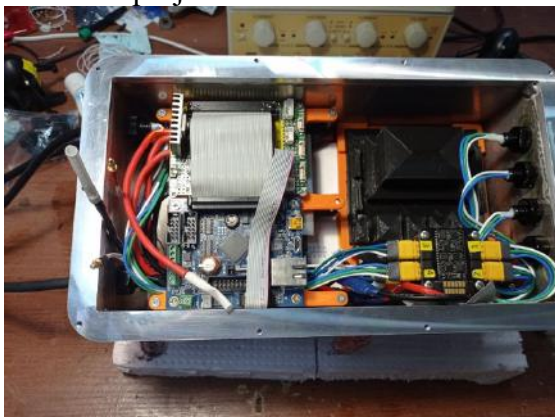

Figure 1 "Improved housing with electronics"

A. General construction

For the device, a bulb for electronics was made of AlMg5 aluminum Figure 1 with a thickness of 4 mm, acrylic with a thickness of 10 mm was chosen for the lid, the cracker adheres to the body through a flange sealed with a round rubber band, we checked the hermiticity of the body using a vacuum pump. For reliable operation of the device, an analysis of the strength of the case was carried out, which showed sufficient rigidity of the body of the deviceFigure 2
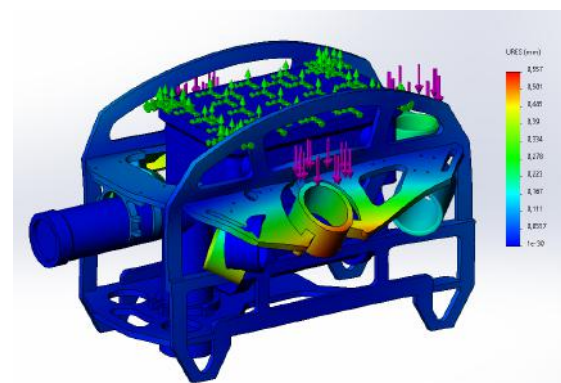

Figure 2 "Structural stress analysis"

B. Torpedo launcher

The torpedo launcher, shown in Figure 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. Figure 3 Render of torpedo launcher.

Figure 3 "Render of torpedo launcher"

IV.   Electrical system

A. Battery

We replaced the lithium polymer batteries Figure 4 with more high-current lithium ion batteries, as we found problems in the fact that under some operating modes of the AUV battery, the batteries we selected lacked current transfer, nothing has changed in the mechanism of disconnecting the device, it is also a magnetic switch

Figure 4 "New battery"

Figure 5 "Battery pack and Ethernet switch"

B. Sensors

1.   Orientation sensors

The vehicle is equipped with IMU and the depth sensor. The team uses 9 Axis AHRS HWT905. 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

2.   Depth sensor

To determine the depth, we use the MS5803-30BA sensor already available on the AUV, which has the following characteristics:

- Measurement range: 0 to 30bar
- Measurement accuracy: 0.2mbar

3.   Hydroacoustic system

As planned, we replaced the hydroacoustic antennas with Russian RT-1.332820-1 antennas, this allowed us to increase reliability and no longer be afraid to damage the antennas, in addition, we replaced the motor controllers to get rid of interference, since the motor control PWM was on the same frequency as a hydroacoustic beacon Figure 6
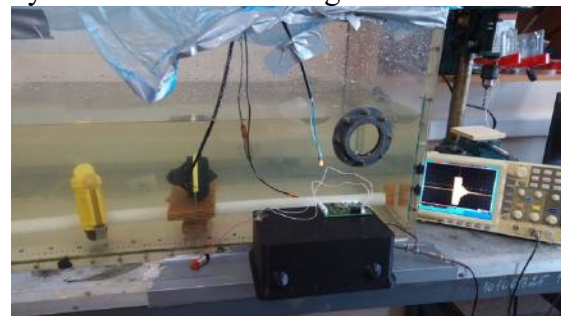

Figure 6 "Validating acoustic interference"

4.   Camera

We replaced expensive industrial IDS cameras with hobby VEYE-MIPI-327s Figure 9, these cameras have a good photosensitive sensor with a good dynamic range, even greater than the previous ones, and are connected via the MIPI interface, which made it possible to get rid of delays and an expensive gigabit switch in the case, in addition to this these cameras are more compact and consume less power, so we have reduced the body of the cameras Figure 7

Figure 7 "Reduce camera case"

C. Communication

For data transfer and connection of peripheral devices, the following interfaces are used: Ethernet, USB, RS-232, 1-Wire, i2c. Devices with high bandwidth are connected to Ethernet (main computer, navigation controller). In the remote control mode, communication with the ground is also through Ethernet. As an ethernet switch, we use mikrotik RB952Ui-5ac2nD Figure 5
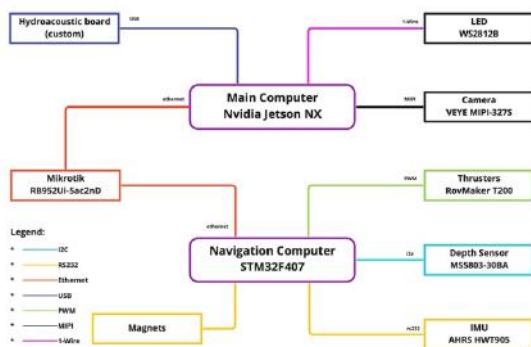

Figure 8 "AUV Network"

V. Software

All AUV software can be classified into highlevel and low-level software. The low-level software runs on the STM32F407-based onboard controller board, under the FreeRTOS real-time operating system. Here low-load computational tasks that require real time are implemented:

- calculating course, roll/depth, speed, and depth controls;
- sending commands to the thrusters;
- control of executive devices and some sensors;
- performing emergency procedures

Tasks with "high" computing requirements are performed on an onboard computer based on Nvidia Jetson NX, with an ubuntu operating system and a ros2 system, we redesigned the system and took orca3 [1] as a basis and adapted it to our needs, we wrote [2] a low-level driver for communicating with a navigation computer.

The main method of object detection is the use of convolutional neural networks. According to the test results, the Single Shot Detector MobileNet V2 demonstrates the best ratio of accuracy and performance. This neural network is based on Inception architecture.
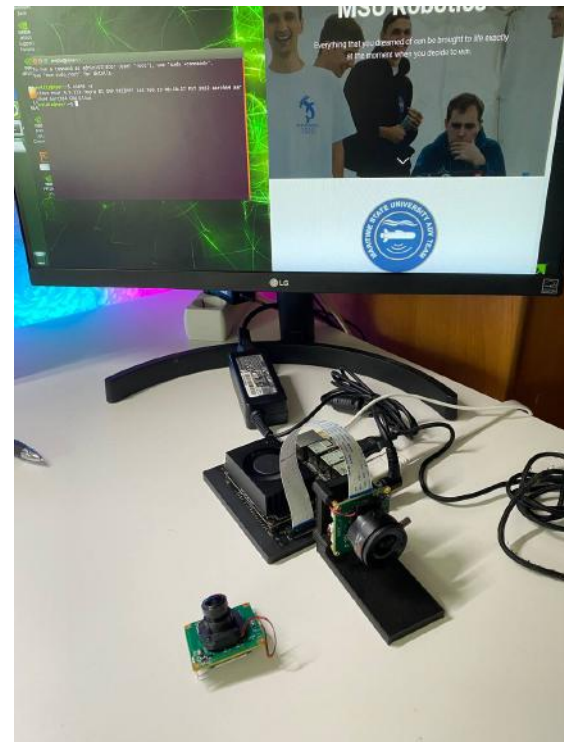

Figure 9 "Nvidia jetson NX and Camera"

Also, traditional recognition algorithms are used for object detection such as color thresholding and contour analysis.

VI. Experimental results

We have successfully tested the device both in the aquarium Figure 11 and in the pool Figure 10, thanks to the tests in the aquarium, we were able to verify the
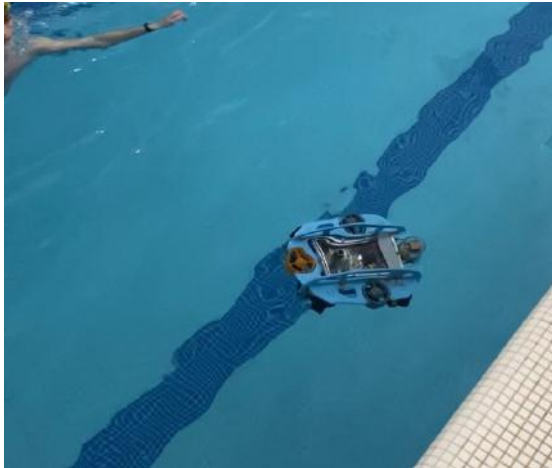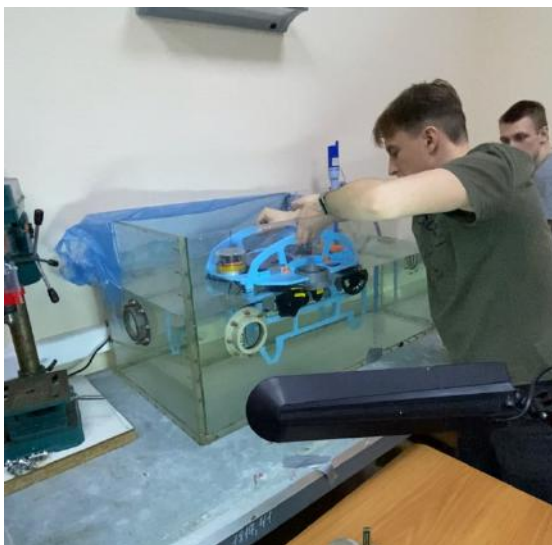
Figure 10 "Tests in pool"

Figure 11 "Tests in aquarium"

tightness of the new case. to adjust the PID regulators, further tests in the basin confirmed that the body is hermitic at great depth and the regulators work as needed. this gave us valuable operational data that allowed us to improve the design of the device, the main difficulty for us were the limitations associated with COVID, but we successfully overcame them since our entire team was successfully vaccinated and we strictly monitored the number of people working in the laboratory and for this year, we did not have a single case of infection.

We also trained a neural network to detect badge using the edgeimpulse service [3], thanks to this service we can easily mark up our dataset, specify the necessary markers, divide the sample into test and train, train the neural network, and export it to the format we need, if necessary, we can always retrain our neural network Figure 12
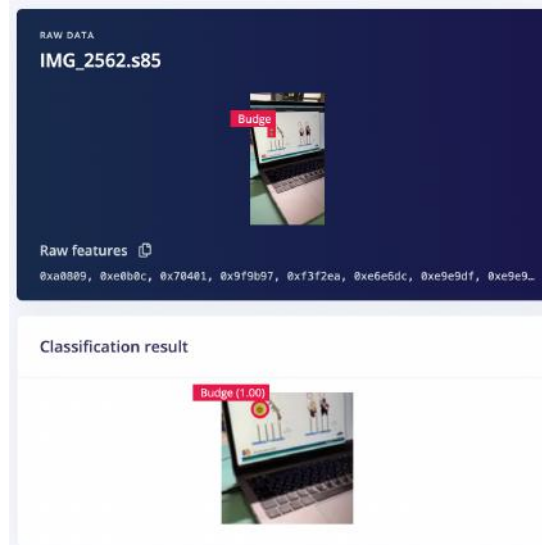
Figure 12 "Classification result"

VII. Acknowledgments

Appendix A: Component Specifications

Component	Vendor	Model/Type	Specs	Cost(if new)	Status
Frame	In-house	polypropylene			
Waterproof Housing	In-house	Aluminum, acrulic			
Waterproof Connectors	RovMaker	M8			
Thrusters	RovMaker	T200	Max thrust: 5.1 kg f Max power: 350 Watts		
Motor Control	Tekko	F4	50A	100$	new
High Level Control	Nvidia	Jetson NX	8G ROM, 256 SSD	1500$	new
Battery		10Ah Li-Ion	16,8 volts 4s		
Inertial Measurement Unit	WitMotion	HWT905			
Vision	VEYE	MIPI-IMX327S		50$	new
Hydrophones	UC&NL	UC&NL RT-1.332820-1			
Algorithms: vision			OpenCV 3, Single Shot Detector MobileNet V2		
Algorithms: acoustics			FFT, triangulation		
Algorithms: localization and mapping			Kalman filter		
Algorithms: autonomy			Implemented by member, behavior tree		
Open source software			OpenCV, ROS2, Orca3		
Team Size (number of people	13				
Testing time: simulation	100 hours				
Programming Language(s)			C,C++,Python		

Appendix B: Mission state machine
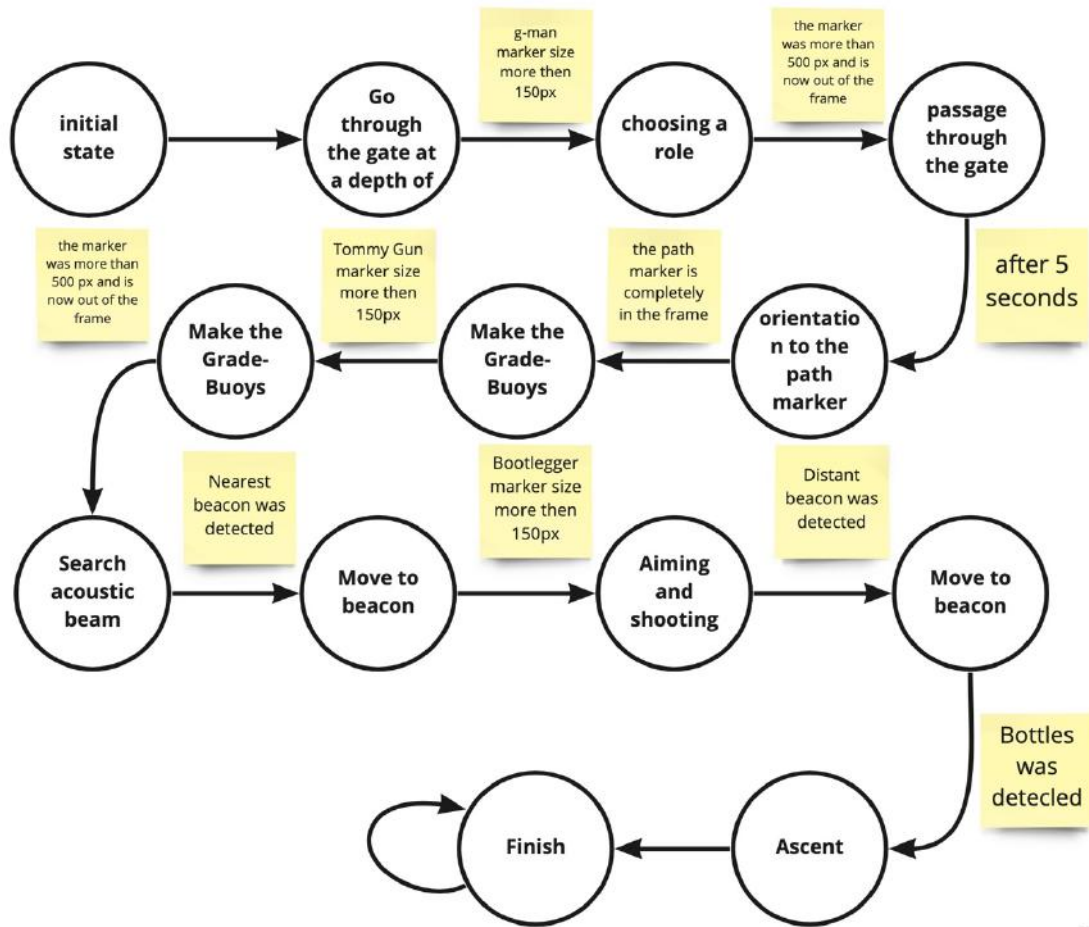
Appendix C: Outreach Activities

Our team members and mentors helped organize the 7th All-Russian Underwater Robotics Competition, which was hosted by MSU on May 7-8, 2022. [4]

Figure 13 "Conducting 8 All-Russian competitions in underwater robotics"

Student members of our team conducted master classes for schoolchildren on underwater robotics. They introduced schoolchildren to the types, construction, and potential of underwater vehicles. The schoolchildren got practical experience in piloting the ROV.

Figure 14 "Conducting a master class for schoolchildren"

We actively participate in scientific conferences on marine robotics. We make reports popularizing our developments.

Figure 15 «Russia Day, holiday June 13»

Figure 16 «Russia Day, holiday June 13»

We actively participate in the popularization of underwater robotics among the population, we participate in city holidays and an exhibition, for example, on the day of Russia on June 13, we presented a pool on the city square where anyone could control our AUV from the remote control

References

[1]   "Orca3," [Online]. Available: https://github.com/clydemcqueen/orca3.

[2]   "msur," [Online]. Available: https://github.com/Photon94/msur.

[3]   [Online]. Available: https://studio.edgeimpulse.com/.

[4]   [Online]. Available: https://robocenter.org/news/346.