RoboBoat 2023: VantTec Technical Design Report
VTec S-III

Max Pacheco, Alexa Arreola, Rogelio Salais, Rodrigo Garza, Abiel Fernandez,
Ian de la Garza, Sebastian Martinez, Eduardo Hernandez, Alejandro Hernandez,
Diego Govea, Daniel Salinas, Alejandra Coeto, Hugo Tonatiuh, Diego Vitales,
Jesus Arteaga, Andres Sanchez, Nadia Garcia, Dany Leo, Adrian Leon, Santiago,
Ian Duran, Alejandro Gonzalez, Alberto Muñoz and Herman Castañeda
Monterrey, Mexico
vanttec@servicios.tec.mx

***Abstract*—In this report we describe the design of VantTec's autonomous boat VTEC S-III and our overall strategy for RoboBoat's 2023 competition. The major changes include an overall redesign of the electronics, communication improvements with the control station, and an improved object detection algorithm**

***Index Terms*—Unmanned surface vehicle, robotics, autonomous boat, GNC system, computer vision**

I. COMPETITION GOALS

Although VantTec's first appearance in RoboBoat was in 2017, this is the first time that any of our current members will have the experience of competing because the older teammates have graduated. That's why our main goal for this competition is to learn the most out of this experience.

Since the navigation tasks are the ones we can solve most confidently and effectively in simulations and in-person, we plan to prioritize their execution. In terms of the order in which the tasks will be solved, next to the starting gates ”Navigate the Panama Canal”, we will solve the ”Northern Passage Challenge” because its solution is less complex than for the other challenges as we only need to rely on the detection of one buoy. Next we plan on tackling the ”Magellan's Route” task, which we'll go through using our LIDAR sensor and we'll count the Manatees and Jellyfish with our ZED camera's object detection system; the next task to solve will be the ”Beaching and Inspecting Turtle Nests”, because it's the last of the ”navigation” tasks, and it's our strong point.

Fig. 1. VTec S-III USV 2023.

Next come the tasks related with the shooting system, from which the ”Feed the Fish” challenge is the most developed one. Our knowledge and resources are limited to do both shooting challenges, so we invested last semester in developing for this task a more complex, but also reliable system, with the possibility to later reuse the aiming system for the ”Fountain of Youth” challenge. The task with less priority due to its complexity and lack of hardware is the ”Ocean Cleanup”, but we still plan on designing a naive solution. Finally, we plan on going through the ”Explore the Coral Reef” gates and finish the run.

These goals are complemented by the vehicle design in a way that the navigation challenges are the most reliable for us because we can trust in the GNC (Guidance, Navigation, and Control) system, since it has been subject of research by previous generations of the team, and it's still nowadays being worked on.

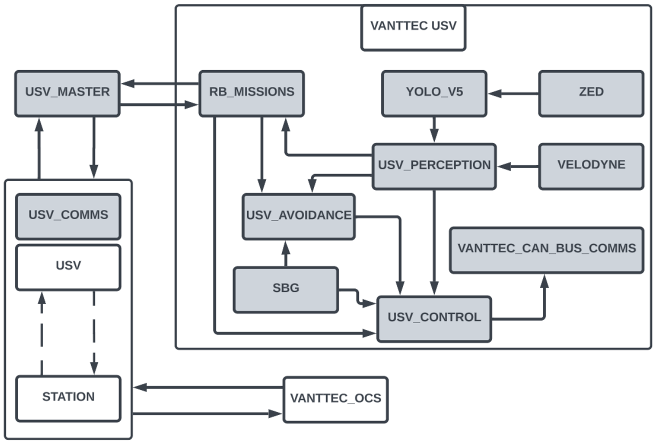

Fig. 2. USV Software Architecture

II. DESIGN STRATEGY

The system design's changes presented below modify our VTec S-III's Robot Operating System (ROS) software architecture in the way shown above (Fig. 2).

A. Communication changes

For long-range communication with the ASV, two applications were developed using Digi Xbee radio. The first one being a series of Python scripts, which used the standard Digi Xbee Python3 library to send ROS topic information wirelessly. To avoid Python version compatibility issues, a local TCP client and server connection was established to forward the Python2 ROS nodes' information to the Xbee transceiver script. The second one being a shell emulator, which forwards instructions from the OCS to the Jetson's operating system, in order to provide general control over the ASV's behavior. This control includes calling and monitoring ROS scripts, executing bash scripts and commands and sending output and feedback to the OCS. The justification for the use of this Xbee Radio-Frequency Module implementation was to stop depending on wifi radio, whose major downside would be its limited range. While using the radios provides less bandwidth, we don't really need a super fast mission status feedback, but rather a reliable one.

B. Integration of new electronic system

As mentioned on last year's Technical Design Report, we designed two new PCBs and now we implemented them to the electronics of the vehicle: the first one controls the thrusters ESCs through PWM signals which are triggered by the commands that our Jetson TX2 sends via CAN bus in autonomous mode and via SBus from our Taranis-x8r radio control in teleoperated mode. The other PCB is the Power Distribution board, that provides overcurrent protection through the usage of fuses for each channel. We use two of these, one to feed the Jetson TX2, IMU, LiDAR, and other peripherals, and the other one is to power the ESCs. The one that powers the ESCs uses relays to kill-switch them with a digital signal in case that an emergency stop is required. This digital kill-switch is bounded to the boat's operating mode, such that it automatically shuts down the thrusters whenever any of these conditions is true: when the ASV is on stop mode, when it goes from autonomous to teleoperated mode, or when the communication stops between the radio transmitter and the receiver. We decided to develop these PCBs in order to have more control on what is being transmitted from the Jetson to the thrusters, and to have a system more reliable than the Arduino we used to have.

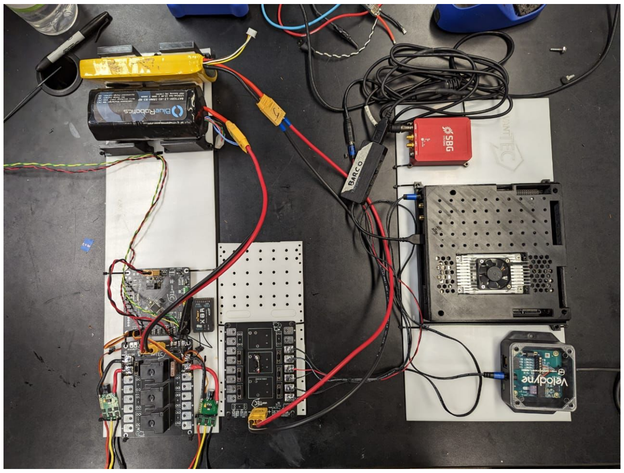

Fig. 3. Electronic Implementation

C. Perception

In previous years our object detection system consisted of training darknet's implementation of YOLOv3 with images of buoys and markers. However, we decided to improve it by upgrading it into using YOLOv5.

Our first approach to classifying each prop and associating them with a color can be seen in the next image, where our camera ZED stereo's video format was sent to a YOLOv5 node that does the object detection, and finally we would apply filters in the bounding box region for color detection of the identified object.

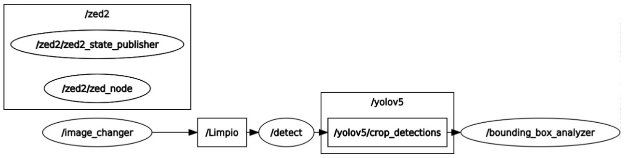

Fig. 4. USV Perception's previous infrastructure

However, the program was slow as it had to run the YOLO algorithm first and then each of the color filters. It was then decided to label our images taking into account the color and the type of prop from the beginning. After applying data augmentation by adding modifications of share, brightness and blur, our data-set of 1,420 images was used to train the Convolutional Neural Network. Our approach was based on using a pre-trained checkpoint with the "nano" size and P6 layer type, which is specialized on extra-large identifications, useful at the moment of having a buoys close to the boat.

Finally, we exported the model from PyTorch's *.pt* format into the *.onnx* format. With this new representation of the weights, we developed a C++ ROS node capable of real time inference in conjunction with OpenCV's dnn module. The later, being used to have a pure C++ implementation that was faster and more capable for our needs.

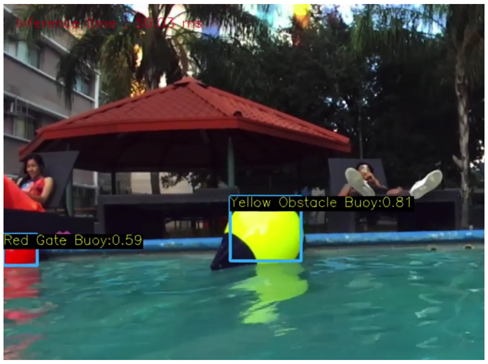

Fig. 5. YOLOv5 for object and color detection

D. *Shooting system development*

In order to solve the "Feed the Fish" and "Fountain of Youth" tasks, a shooting system mechanism was needed, so we started with the development of the first one mentioned's solution, as a ball shooting system can be tested more easily than a water shooting system. This mechanism works by capturing with the ZED camera the position of the target, and translating it to the reference frame of the shooter, calculating the trajectory, making it aim, shoot and reload until all the balls have been deployed. It consists of three subsystems: a propulsion system, made of brushless motors and rubber wheels that transfer the kinetic energy to the balls; a stabilization system, in charge of the aiming and handling the external generated perturbations; and the reloading system, that works as a storing mechanism for the balls, while deploying them to the shooting barrel, one by one, through a spinning pinwheel.

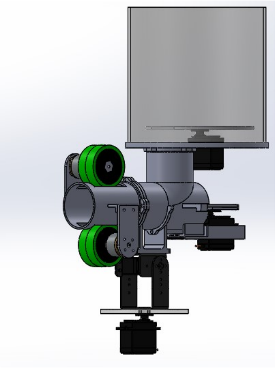

Fig. 6. Shooting System Design

III. TESTING STRATEGY

The way in which we test the progress made is first through simulations performed in Gazebo and RViz. For this, we had to create virtual environments similar to real life, to test our solutions to the challenges of the competition. This environments have several iterations for the USV to test with, simulating the uncertainty of the competition course task arrangement, and conditions.

After achieving positive results in the simulation, we tested the boat's behavior in an Olympic-sized pool at our university. We tried to adapt it as much as possible to the context of the competition by adding self-made obstacles similar to the characteristics of the official buoys, markers, and the other props of the competition.

IV. CONCLUSIONS

For this season we focused on redesigning our power distribution system, improving communication with the boat through the Xbee radios, improving our object detection system by exploring more updated algorithms, and developing a shooting system against perturbations.

Thanks to the pandemic's decreasing levels of threat in our country during the past year, we have been able to test more of our progress in the real world, rather than just in the theory, which has helped us make several experiments and fix as much mistakes as possible, redesigning our electronics system, improving the reliability of our USV. This in turn has allowed us to perform more tests, as there is decreased downtime for repairs or maintenance during the competition.

Every year it is a challenge to familiarize ourselves with the work of our predecessors with respect to the developments on the ship, as well as to harness and develop the individual talents of the team members. Every day we continue to learn and be amazed at what we can create with time and teamwork.

ACKNOWLEDGMENTS

This work was supported by: SBG Systems, RoboNation, Velodyne LiDAR, NVIDIA, ZF Group. Finally, VantTec appreciates the support from the university, Tecnológico de Monterrey and to our advisor Dr. Herman Castañeda and Jesús Arteaga.

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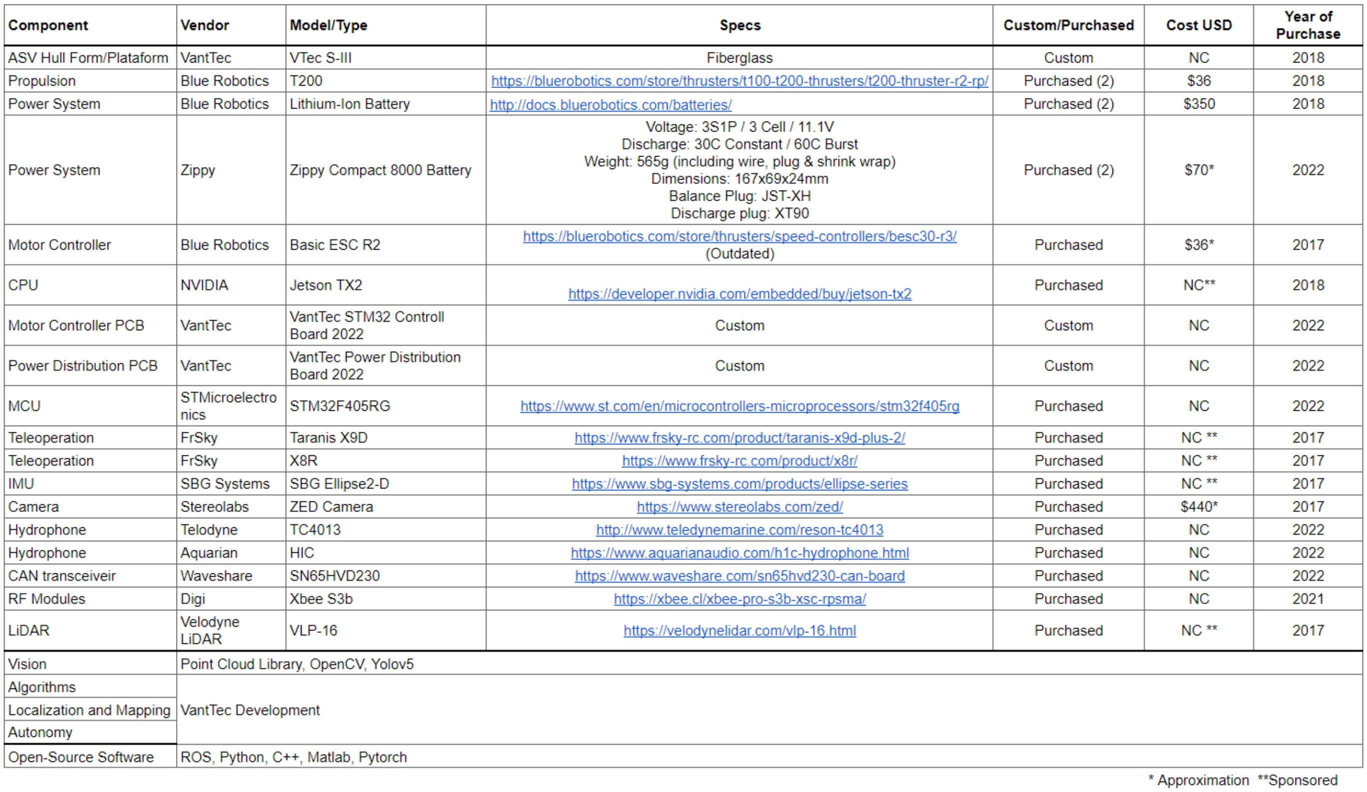
APPENDIX A: COMPONENT SPECIFICATIONS



Component	Vendor	Model/Type	Specs	Custom/Purchased	Cost USD	Year of Purchase
ASV Hull Form/Plataform	VantTec	VTec S-III	Fiberglass	Custom	NC	2018
Propulsion	Blue Robotics	T200	https://bluerobotics.com/store/thrusters/t100-t200-thrusters/t200-thruster-r2-rp/	Purchased (2)	$36	2018
Power System	Blue Robotics	Lithium-Ion Battery	http://docs.bluerobotics.com/batteries/	Purchased (2)	$350	2018
Power System	Zippy	Zippy Compact 8000 Battery	Voltage: 3S1P / 3 Cell / 11.1V Discharge: 30C Constant / 60C Burst Weight: 565g (including wire, plug & shrink wrap) Dimensions: 167x69x24mm Balance Plug: JST-XH Discharge plug: XT90	Purchased (2)	$70*	2022
Motor Controller	Blue Robotics	Basic ESC R2	https://bluerobotics.com/store/thrusters/speed-controllers/besc30-r3/ (Outdated)	Purchased	$36*	2017
CPU	NVIDIA	Jetson TX2	https://developer.nvidia.com/embedded/buy/jetson-tx2	Purchased	NC**	2018
Motor Controller PCB	VantTec	VantTec STM32 Controll Board 2022	Custom	Custom	NC	2022
Power Distribution PCB	VantTec	VantTec Power Distribution Board 2022	Custom	Custom	NC	2022
MCU	STMicroelectronics	STM32F405RG	https://www.st.com/en/microcontrollers-microprocessors/stm32f405rg	Purchased	NC	2022
Teleoperation	FrSky	Taranis X9D	https://www.frsky-rc.com/product/taranis-x9d-plus-2/	Purchased	NC **	2017
Teleoperation	FrSky	X8R	https://www.frsky-rc.com/product/x8r/	Purchased	NC **	2017
IMU	SBG Systems	SBG Ellipse2-D	https://www.sbg-systems.com/products/ellipse-series	Purchased	NC **	2017
Camera	Stereolabs	ZED Camera	https://www.stereolabs.com/zed/	Purchased	$440*	2017
Hydrophone	Telodyne	TC4013	http://www.teledynemarine.com/reson-tc4013	Purchased	NC	2022
Hydrophone	Aquarian	HIC	https://www.aquarianaudio.com/h1c-hydrophone.html	Purchased	NC	2022
CAN transceiveir	Waveshare	SN65HVD230	https://www.waveshare.com/sn65hvd230-can-board	Purchased	NC	2022
RF Modules	Digi	Xbee S3b	https://xbee.cl/xbee-pro-s3b-xsc-rpsma/	Purchased	NC	2021
LiDAR	Velodyne LiDAR	VLP-16	https://velodynelidar.com/vlp-16.html	Purchased	NC **	2017
Vision	Point Cloud Library, OpenCV, Yolov5					
Algorithms	VantTec Development					
Localization and Mapping						
Autonomy						
Open-Source Software	ROS, Python, C++, Matlab, Pytorch					

* Approximation **Sponsored