VantTec Technical Design Report 2019

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***Abstract*—This technical design report addresses the strategy use by the group VantTec for the international competition RoboBoat 2019. This includes creating a modular software system to simplify challenge development, and managing members according to area of expertise and experience on the group. Furthermore, the creative decisions for new hardware and software subsystems, as well as experimental results on subsystems such as object detection, map creation and a backstepping controller.**

***Index Terms*—Unmanned Surface Vehicles, USV navigation, robotics, computer vision, artificial intelligence, GNC system, autonomy**

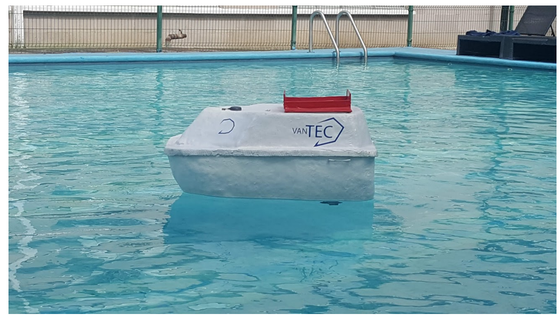

Fig. 1. Boat navigating in a pool.

I. Competition Strategy

Experience is a key asset for a competition such as RoboBoat. This year, taking advantage of experience from the 2017 and 2018 editions, the group decided the approach for this year would be to create a modular system and focus even more on the software than last year. Similarly, a solution was found of implementing two different approaches for the required task of passing through the start gate, a task the team was unable to perform last year due to an overly complex system.

A. Course Approach

RoboBoat 2018 ended with a prize for VantTec, but zero points were obtained during the qualification days. The team's choice to be bold and perform every task concluded in an unsuccessful participation with a considerable amount of experience and testing for future editions. In RoboBoat 2019, the group will try again to accomplish all of the tasks, but this time with priority on scoring in tasks the vehicle is ready for.

The boat has been tested to pass through the start gate with buoys instead of markers, creating the chance to start working plainly on other tasks that can use the same technical approaches. The group will focus on accomplishing Speed Challenge and Find the Path. Moreover, testing is still ongoing on subsystems for Automated Docking and Raise the Flag, a decision on which tasks to focus will be made according to how well each subsystem performs before the competition.

B. Time and Members Management

The Fall semester of 2018 was used to improve some of the technologies previously developed, as well as planning on the new technologies that had to be implemented. The Spring semester of 2019 has been used to test in the water every subsystem already working on simulation and at the laboratory, as well as researching ways to easily include new subsystems around the most advanced areas. This led to a very specific way to divide the team and the school year.

The mechanical and electrical sub-teams kept working mostly on the same hardware, with the addition of a few new components. On the other hand, the software area divided into different objectives. Older members focused on the research, while newer members focused on system migration, integration, configuration and testing new subsystems.

Moreover, by the middle of the Spring semester, the boat was already been tested in-water in autonomous mode. Giving us two months to improve the software, until the last two weeks. This final period of time is set to be a parallel work on subsystem details, system integration and in-water testing of the capabilities.

II. Design Creativity

A. Hardware

The main relevant decision surrounding the vehicle's hardware was to reuse the hull (Fig.1) used in RoboBoat 2018. However, several upgrades were implemented in order to improve the practical aspects of the design, as well as a new electronic circuit board and a different electrical setup.

The new circuit board (Fig.2) is a smaller version of 2018 power circuit, to easily connect an Arduino Nano microcontroller, thruster drivers, and other components. As well, 3D printed bases were included to easily assemble the electrical

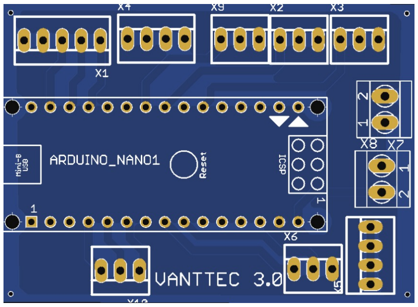

Fig. 2. Electrical Circuit Board.

Fig. 3. ZED Camera.

setup inside of the vehicle, so that it is modular and more practical to remove for maintenance. Moreover, a Jetson TX2 will be the new processor for the boat, still expected to arrive before competition dates.

Other new hardware features include a ZED Camera, already in use, and a VLP-16 Velodyne Lidar, still expected to arrive. The need to measure distances toward objects is vital for obstacle avoidance and path planning. Precise laser sensors with long distance ranges like Lidar are very expensive, which is why the main sensor on the vehicle is a ZED Camera, a long range stereo vision camera. The ZED camera is robust and well documented, it's RGB video feed is used for obstacle detection while the depth cloud is used for distance estimation.

For the mechanics of the vehicle, a water seal was implemented on the inside of the top part of the boat. Similarly, a leak on the hull was fixed with polyurethane. Finally, the vehicle went back to the workshop to adapt it for the new hardware.

B. Software

To create a modular system for the software, all of the code was into Robot Operating System (ROS), using the Kinetic version. Some members had experience using ROS, and it was intended to be used on RoboBoat 2018. One of the problems last year was the amount of time the team had to invest integrating the software to work independently, together and testing new functions. With the use of ROS, the subsystems are tested individually, managing to create simulated data to test controllers, map creation, on-site detection and path planning algorithms, before testing on the actual boat.

A second improvement on the software, was to develop the dynamic model of the vehicle in order to test controllers for speed and heading. The model was developed in Simulink after pool experiments, and it will be used to create a Gazebo simulation environment for future editions of RoboBoat.

TABLE I
PERFORMANCE COMPARISON BETWEEN YOLOV2 AND YOLOV3

Test	class 0 (AP%)	class 1 (AP%)	mAP(%)	IoU%	F1 Score	FPS
YOLOv2	62.20	43.32	52.76	41.70	0.63	**41**
YOLOv3	**74.93**	**87.84**	**81.38**	**62.73**	**0.85**	39

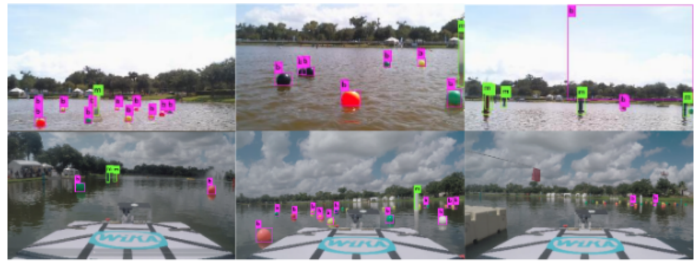

Fig. 4. Detection results from experiment conducted on YOLOv2.

To improve obstacle detection, a new data-set for neural network training was created. The data-set consisted mainly of images taken from videos filmed with cameras mounted on top of participation boats at Roboboat 2018. With this particular data-set, context error in obstacle detection is avoided.

III. EXPERIMENTAL RESULTS

A. Obstacle Detection

The group focused on evaluating different systems that detect buoys and how the system would perform without augmenting the data-set with synthetic images as done in previous work [1]. The results show that very accurate performance can be achieved as the networks were able to capture important features of objects of interest.

Visual and numerical results of the four different precision tests using YOLO as the backbone of the vision system of the autonomous boat are shone below. Every table shows the *average precision* for each of the classes. The buoys classes is refereed as *class 0* and the markers class as *class 1*. The mean average intersection over union is presented as *IoU* the precision as *mAP*, and *F1 scores* are the overall tests scores. Finally, average is shown *FPS* while testing with video input with a GeForce GTX 1080.

YOLOv3-based detector outperformed significantly the older version and both lightweight detectors are significantly faster than those of Table I. The team decided to use

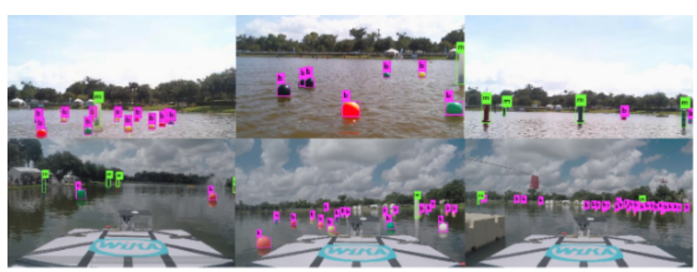

Fig. 5. Detection results from experiment conducted on YOLOv3.

TABLE II
PERFORMANCE COMPARISON BETWEEN TINY YOLOV2 AND TINY YOLOV3

Test	class 0 (AP%)	class 1 (AP%)	mAP(%)	IoU%	F1 Score	FPS
Tiny YOLOv2	36.24	28.94	33.04	30.13	0.45	56
Tiny YOLOv3	**60.33**	**73.73**	**67.03**	**52.29**	**0.71**	**60**

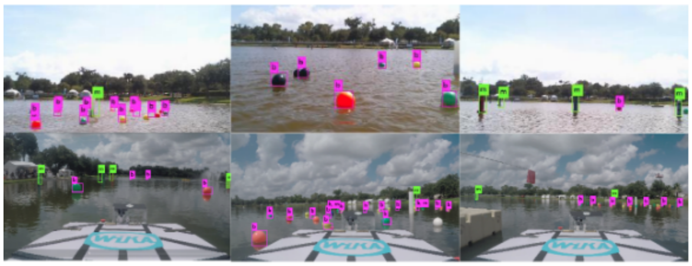

Fig. 6. Detection results from experiment conducted on the lightweight version of Tiny YOLOv2.

the lightweight version of YOLOv3 in the robot, although YOLOv3 is more accurate. This is because an observation that both detectors achieve good results, however, the computation capabilities of the boat are limited, and concerning real-time processing to perform subsequent tasks that involve tracking, depth estimation and navigating.

B. Mapping

The image coordinates corresponding to an obstacle are identified and the distance in meters is determined using the depth point cloud given by the zed camera (Fig. 8). This distance is then used to create a map of the vehicle's environment with a 20mx20m range. The detected obstacles appear as white circles (Fig. 9). This map is then used for path planning.

C. Path Planning

An A* algorithm was implemented in order to create a path the boat could navigate. Fig. 10 represents a test of the algorithm on a simplified map, simulating obstacles that could appear in the boat's environment.

Fig. 7. Detection results from experiment conducted on the lightweight version of Tiny YOLOv3.

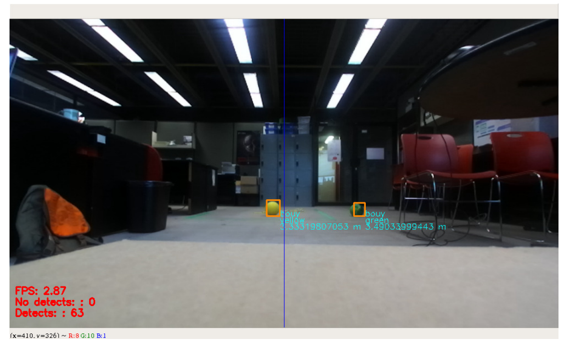

Fig. 8. Detection results from experiment conducted with ZED Camera.

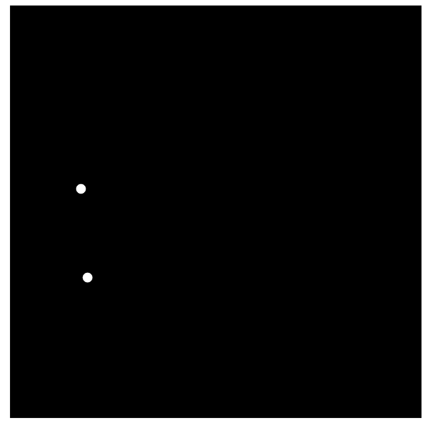

Fig. 9. Mapping results from experiment conducted with ZED Camera.

D. Control Theory

The model developed allowed for a better controller design [2]. Fig. 11 represents a heading controller working on simulation. Fig. 12 represents the heading controller working on a pool experiment. Both controller output have a similar sine wave input signal. The start of Fig. 12 was perturbed as the vehicle was searching for the correct desired heading, but eventually aligned with an acceptable performance.

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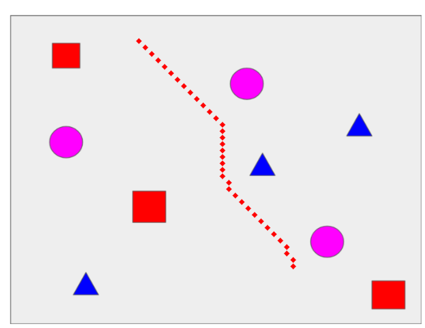

Fig. 10. A* algorithm on a simple map.

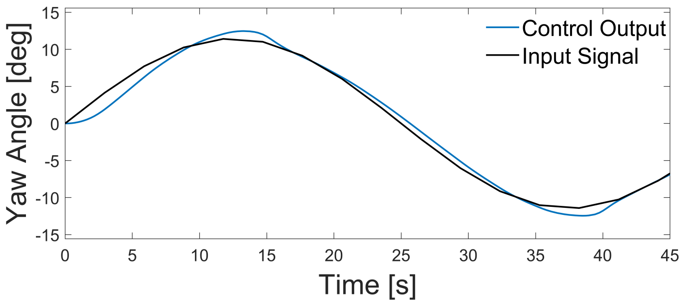

Fig. 11. Heading controller on simulation

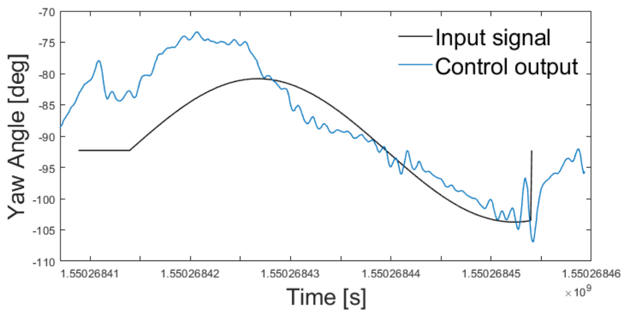

Fig. 12. Heading controller experiment.

Proshow, RoboNation, Velodyne Lidar, Nvidia, Vectornav, Runners North and Tecnologico de Monterrey.

REFERENCES

[1] I. Navarro, A. Herrera, I. Hernandez, L. Garrido, "Data Augmentation in Deep Learning-based Obstacle Detection System for Autonomous Navigation on Aquatic Surfaces", Mexican International Conference on Artificial Intelligence, 2018.

[2] A. Gonzalez, H. Castaneda, "Modeling, Identification and Control of an Unmanned Surface Vehicle", AUVSI XPONENTIAL, 2019.

APPENDIX A: COMPONENT SPECIFICATIONS

See Table III.

APPENDIX B: OUTREACH ACTIVITIES

A.INCmty

INCmty is the largest festival of entrepreneurship in Latin America, based in Monterrey, Mexico. Last November,we participated on INCmty 2018 with a stand where we promoted unmanned and autonomous vehicle technologies, representing our universitys faculty of engineering, Escuela de Ingeniera y Ciencias.

Links:
https://incmty.com/
https://bit.ly/2QywmC3

B.Congreso Automatizacin y Tecnologa(AT)

AT is an international mechatronics congress organized by students from Tecnolgico de Monterrey. In this years edition, AT15, we participated with a conference called Robtica y su impacto" (Robotics and its impact), given by Alejandro Gonzalez. At this conference, we explained the bases or robotics and its impact on society. We also gave a "Introduction to computer vision course".

Links:
http://congresoat-mecatronica.com
https://bit.ly/2IkDM8j

C.Conexion Tec

Conexion TEC is an event organized by Tecnolgico de Monterreysfaculty of engineeringto highlight the best student projects from the semester. We participated with the technology developed for RoboBoat 2017.

Links:
https://www.facebook.com/conexiontec/
https://www.vanttec.mx/news/hoy-estuvimos-en-conexion-tec-con-dos-proyectos-del-grupo-demostramos

D.Conecta

Conecta is an on-lin emagazine from Tecnolgico de Monterrey. A reporter interviewed us and published it on the site, promoting our achievements.

Links:
https://tec.mx/es/noticias/nacional/educacion/sobresalen-alumnos-del-tec-en-torneo-de-vehiculos-autonomos-acuaticos

E.AUVSI XPONENTIAL

AUVSI XPONENTIAL is the one event that brings together the entire unmanned systems community to share ideas, collaborate across markets, capitalize on best practices and emerging trends and harness the power of unmanned technology for your business.

Links:
https://www.xponential.org/xponential2019/public/enter.aspx
https://www.vanttec.mx/news/yesterday-our-team-leader-alejandro-gonzalez-gave-a-talk-at-auvsi

F.Born to Be Tec

An event for motivating students to become part of Tecnolgico de Monterrey. We represented one of the most outstanding projects in the engineering department.

Links:
https://www.vanttec.mx/news/imagenes-del-taller-de-vision-computacional-que-impartimos-en-el-btec2018

G.PrepaTec Career Fair

An event for motivating students from Tecnolgico de Monterrey High Schools to become part of Tecnolgico de Monterrey. We represented one of the most outstanding projects in the engineering department.

Links:
https://www.vanttec.mx/news/as-an-interdisciplinary-team-we-love-to-help-at-career-fairs-to-showcase

H.Yeii

Young Entrepreneurship and Innovation International program dedicated to encourage entrepreneurship and innovation among children and youth. We gave a talk about our robotics group VantTec and the possible future applications of our technology.

Links:
http://yeii.org/

H.WIT

Women in Tecnology is a community committed to the empowerment of all women in the area of technology. VantTec participated presenting our proyect and the importance the women members of the group have.

Links:
ttps://www.facebook.com/womenintechmx/

TABLE III
COMPONENT SPECIFICATIONS

Component	Vendor	Model/Type	Specs	Cost (if new)
ASV Hull	Own design	VantTec 3.0	Fiberglass	NN
Propulsion	Blue Robotics	T200	http://docs.bluerobotics.com/thrusters/t200/	NN
Power System	Blue Robotics	Lithium-ion Battery	http://docs.bluerobotics.com/batteries/	NN
Motor controls	Blue Robotics	Basic ESC R2	https://www.bluerobotics.com/store/retired/besc30-r2/	NN
CPU	NVIDIA	Jetson TX2	https://developer.nvidia.com/embedded/buy/jetson-tx2	600
IMU	VectorNav Technologies	VN-200	https://www.vectornav.com/products/vn-200	NN
Camera	Stereolabs	ZED Camera	https://www.stereolabs.com/zed/	450
Teleoperation	FrSky	Taranis X9D Plus	https://www.frsky-rc.com/product/taranis-x9d-plus-2/	NN
Teleoperation	FrSky	X8R	https://www.frsky-rc.com/product/x8r/	NN
RF Modules	Digi	XTend	https://www.digi.com/products/xbee-rf-solutions/ boxed-rf-modems-adapters/xtend-900mhz-rf-modemsspecifications	NN
Aerial vehicle	DJI	Phantom 4 Pro	https://www.dji.com/phantom-4-pro	NN
Hydrophone	Telodyne	TC4013	http://www.teledynemarine.com/reson-tc4013	NN
Lidar	Velodyne Lidar	VLP-16	https://velodynelidar.com/vlp-16.html	4000

Vision	Darknet, YOLO, OpenCV
Localization and Mapping	Robot Operating System (ROS), OpenCV
Team Size	27 members
Expertise Ratio	10 vs.11 vs.7(hardware vs. software vs. trainees)
Testing time: simulation	5 months
Testing time: in water	1 month
Inter-vehicle communication	Bluetooth(UAV-station) and RF (USV-station)
Programming	Python 2.7/3, C++, MATLAB/Simulink, Arduino, Java