MTM Trinity Technical Design Report

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***Abstract*—This technical design report discusses the conceptual problems presented to the student group VantTec while preparing for the international competition RoboBoat 2018. First, managing the group members and the strategy to approach the competition with computer vision and GPS based navigation. Second, the design innovations on the mechanical and software subareas, and the overall system. Finally, the experimental results and the in water experiments to be performed before the competition.**

Keywords—Autonomous, computer vision, navigation, robotics, unmanned vehicles

I. INTRODUCTION

Robotics competitions can introduce undergraduate students into state of the art projects and current research objectives on different fields. As well, undergraduate students can use this type of competitions to develop their technical skills in their areas of interest.

VantTec is a multidisciplinary student group at Tecnológico de Monterrey, focused in the research and development of unmanned autonomous vehicles. VantTec is divided internally into three subareas according to the majors available in the university and the skills required for the development of an autonomous vehicle. These subareas are Mechanical and Electronics Engineering, Communications and Software Engineering, and Control Engineering. VantTec is integrated by undergraduate students coursing Mechatronics Engineering, Digital Systems and Robotics Engineering and Computer Science Engineering.

II. COMPETITION STRATEGY

The competition course consists of five different missions, with only one mandatory task. Considering the group's experience from RoboBoat 2017, our vision for RoboBoat 2018 is to try to complete all of the missions, in order to achieve a higher score. However, we are focused on relying on the group's history and the group's subarea with the higher number of members. Our approach towards the competition is to develop each part of the system separately, with a final software integration of all the subsystems.

A. Experience and New Members

On RoboBoat 2017, the group received the "Special Drone Award" for being the only team able to deploy an Unmanned Aerial Vehicle (UAV) from an Unmanned Surface Vehicle (USV) platform. Therefore, we will try to improve our results on the interoperability challenge, incrementing the autonomous capabilities of the UAV, including communications and computer vision. Likewise, on RoboBoat 2017 we did not perform accurately the automated docking. That being the case, we intend to develop the software necessary to control the vehicle and obtain all the competition points that do not include using the hydrophone.

On the other hand, most of the newer members of the group are majoring in software related areas. Consequently, we decided to implement machine learning and computer vision for sensing, and invest time on the code architecture, increasing the overall system capabilities. In opposition, we contemplated a shorter period designated for in water tests, prioritizing the software efficiency.

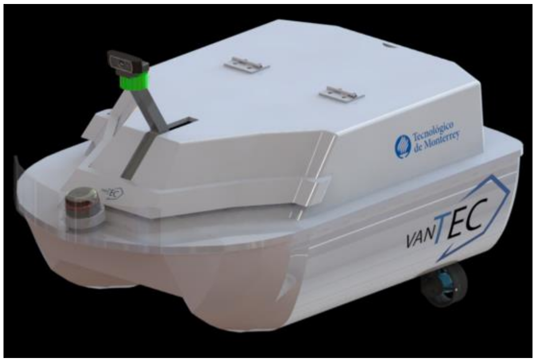

Fig. 1. MTM Trinity SolidWorks design.

B. Course Approach

For the course, our ideal concept was to have a different approach on each task, using computer vision, LiDAR and GPS waypoint navigation. We had to change this decision because we were not able to afford a LiDAR for this year's competition.

The next approach was to implement computer vision on every task, simplifying the overall system, and merging GPS waypoint navigation into the tasks that may require it according to our solution approach.

First, both "Autonomous Navigation" and "Speed Challenge" have a computer vision and GPS navigation approach. The GPS navigation will set the points the USV needs to navigate through. In addition, the computer vision will aid on the heading of the navigation, so it does not lose track of its local position.

Moreover, "Automated Docking" has our most complex approach. For the UAV, we developed an Android mobile application to set the GPS waypoints, take a picture of the 7-segment display, recognize the number and send it to the control station. The USV will receive the number of the dock, will look for it with computer vision so it can align and get closer in order to dock. We will not be performing the task involving the hydrophone to invest our time in other subsystems.

Furthermore, "Find the Path" has a computer vision approach. Ideally, this task was going to be performed with a LiDAR, but we had to adapt to our situation. We intend to use computer vision to create a map of the obstacle field. This way, we can use a path planning algorithm and navigate through previously known waypoints.

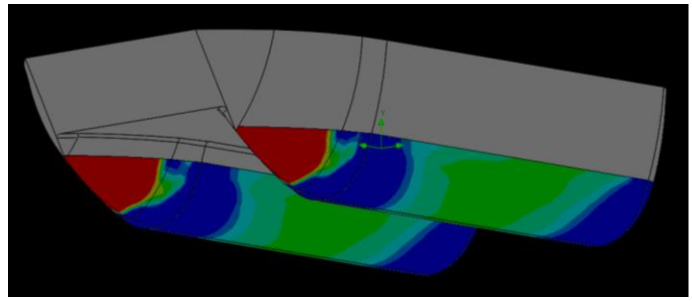

Fig. 2. Twin hull SolidWorks hydrodynamic analysis and simulation.

Finally, although we thought of a computer vision approach for "Follow the Leader", we do not think we will have enough time to implement it. We hope that this decision helps us on scoring as most points as possible on all the other tasks.

III. Design Creativity

A. Mechanical Design

The MTM Trinity (Fig. 1) is the third USV designed and built by the group. We decided to keep the twin hull design similar to the MTM Definity First, USV used on RoboBoat 2017, and to the WAM-V USV-14 [1], [2] used for RobotX. Twin hull arrangements are often implemented for lateral stability and increasing available deck space [3], characteristics convenient for our approach. The lateral stability will allow better quality on the computer vision input, reducing the camera disturbance. Similarly, increasing the deck space involves increasing platform for the UAV to deploy and land if necessary.

The new design adds functionalities our past vehicles ignored. The superstructure has gates to access the main computer and electronics. Additionally, a 3D printed mechanism allows the camera to change its position. The first position is to serve as an input for the computer vision algorithm. The second position is to avoid obstructing the UAV while performing deployment and landing maneuvers.

The MTM Trinity twin hull was designed using the computer-aided drafting software SolidWorks. With simulations, the hydrodynamic design of ship hull forms can be optimized [4]. We performed hydrodynamic analysis and simulations using the SolidWorks Flow Simulation (Fig. 2) package in order to improve the performance of the design.

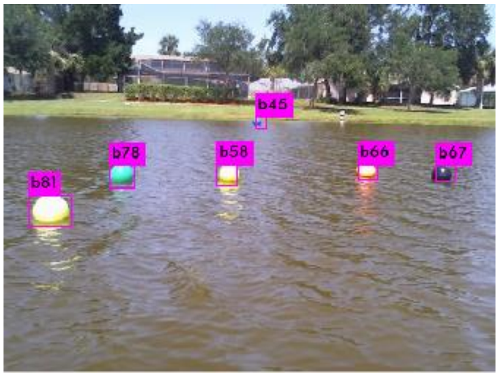

Fig. 3. Detection of buoys using machine learning tools.

B. Computer Vision

To improve the computer vision subsystem, we decided to implement machine learning tools and the OpenCV library. We used the open source neural network framework, Darknet, and the real time object detection system, YOLO. In favor of train the neural network, we gathered images taken on RoboBoat 2017 and images with similar shapes to the buoys used in the competition. After detecting the objects in the image, we create a bounding box for each object and we classify them.

Data collected from the neural network is used to create a map. The bounding box parameters and the physical object dimensions allow us to obtain the distance and angle of each object in reference to the USV. Finally, OpenCV filters are implemented to know the color of the object, tool for logical decisions in certain challenges.

C. Overall System

The overall system has a network to communicate the different subsystems and their respective languages. The control station communicates with radiofrequency modules to the USV, and with Bluetooth to the UAV Android mobile application. The computer vision and LiDAR subsystems send data to the navigation subsystem. The navigation subsystem integrates the Robotics Operating System middleware and MATLAB to create a map, acquire GPS and IMU data, plan a trajectory and use it to navigate. An Arduino receives the output and performs the control of the actuators. As well, the Arduino is connected to a radiofrequency receiver acquiring information from a radiofrequency controller used to switch between autonomous navigation and manual control.

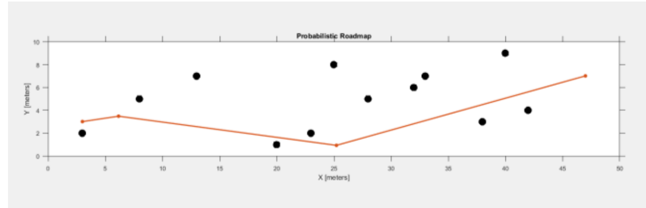

Fig. 4. Robotic System Toolbox Probabilistic Roadmap path planner simulation.

IV. Experimental Results

The computer vision subsystem (Fig. 3) detects and creates an accurate bounding box for the buoys. It is capable of performing in real time or other time settings. Additionally, the path planning algorithm has been tested to work with a previously known map (Fig. 4).

Because of problems with the vehicle construction and the project funding, we have not made any in water tests. On the next two weeks before the competition, we have scheduled experiments to test simple navigation tasks. First, we are going to test GPS waypoint navigation and its accuracy. Next, we are going to test our computer vision obstacle detection while navigating. Then, we are going to simulate competition challenges, with each of the approaches specified in Section II.

We are not certain about how far we are going to get before the competition dates. However, in our projection, the system will have a performance adequate to test our approaches in the competition course on Reed Canal Park.

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References

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Appendix A: Component Specifications

Component	Vendor	Model/Type	Specs	Cost (if new)
ASV Hull	Own design	MTM Trinity	Fiberglass hull and superstructure.	$300
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	Acer	Aspire 7	https://www.acer.com/ac/es/ES/content/series-features/aspire7	NN
IMU	VectorNav Technologies	VN-200	https://www.vectornav.com/products/vn-200	NN
Camera	Logitech	C920	https://www.logitech.com/en-ca/product/hd-pro-webcam-c920	$50
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-modems#specifications	$1000
Aerial vehicle	DJI	Phantom 4 Pro	https://www.dji.com/phantom-4-pro	NN
Vision	Darknet, YOLO, OpenCV			
Localization and Mapping	MATLAB Robotics Operating Toolbox, Robotics Operating System (ROS)			
Team Size	19 members			
Expertise Ratio	10 vs. 14 (hardware vs. software)			
Testing time: simulation	3 months			
Testing time: in-water	2 weeks			
Inter-vehicle communication	Bluetooth (UAV-station) and RF (USV-station)			
Programming	Python 2.7, C, MATLAB, Arduino			

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 2017 with a stand where we promoted unmanned and autonomous vehicle technologies, representing our university's faculty of engineering, "Escuela de Ingeniería y Ciencias".

Links:
https://incmty.com/
https://www.facebook.com/pineapplemi/videos/299607777112946/UzpfSTE0ODM3ODg5ODE2OTEzNDk6MTc2MzE5OTQ5MDQxNjk2Mg/
https://www.facebook.com/vantTEC/posts/1763338480403063

B. Congreso Automatización y Tecnología (AT)

AT is an international mechatronics congress organized by students from Tecnológico de Monterrey. In this year's edition, AT14, we participated with a conference called "Botes Autónomos" (*Autonomous Boats*), given by Alejandro Gonzalez. At this conference, we explained the concepts behind designing and programming an autonomous vehicle and our work with ASVs.

Links:
http://congresoat-mecatronica.com/
https://www.facebook.com/vantTEC/photos/pb.1483788981691349.-2207520000.1528076595./1974627399274169/?type=3&theater

C. BIT Binational Innovation Technology Hackathon

BIT was the first binational hackathon, based on both Nuevo Laredo, Mexico and Laredo, Texas. VantTec was present with a small talk about the group's achievements on RoboBoat 2017 and a stand displaying the technology. As well, we had a representative serving as a mentor for the participants.

Links:
https://www.facebook.com/BIThackaton/
https://www.facebook.com/vantTEC/photos/a.1825908764146034.1073741830.1483788981691349/1895866863816890/?type=3&theater

D. Conexion TEC

Conexion TEC is an event organized by Tecnológico de Monterrey's faculty of engineering to 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.facebook.com/vantTEC/posts/1770938339643077

E. Día IMT

"Día IMT" is the day the students of the Bachelor in Mechatronics Engineering celebrate the major's anniversary on campus. VantTec was present displaying the MTM Definity First and explaining first year students how this type of technology works.

Links:
https://www.facebook.com/pg/saimt.mty/photos/?tab=album&album_id=2147020658657546
https://www.facebook.com/vantTEC/posts/1753908504679394

F. Conecta

Conecta is an on-line magazine from Tecnológico de Monterrey. A reporter interviewed us and published it on the site, promoting our achievements.

Links:
https://tec.mx/es/noticias/nacional/investigacion/crean-primer-barco-robot-mexicano