TUMI
robotics

PUCP

RobotX Project Proposal

Implementation and validation of autonomous USV and UAV robotic system for maritime environments

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<tr><th colspan="6">Emission and change control</th></tr>
<tr><td>Ver N°</td><td>date</td><td>description</td><td>produced by:</td><td>revised by:</td><td>approved by:</td></tr>
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</table>

Technical Approach and Justification

The Pontificia Universidad Católica del Perú (PUCP) and Tumi Robotics have been participating in many robotics systems projects in association with national financing entities. Tumi Robotics is in a project named “Implementation of an Unmanned Robot Catamaran (USV) for Real Time Monitoring of Parameters Oceanographic and Marine Ecosystem in the Coastal Zone of Huarmey” financed by the Programa Nacional de Innovación en Pesca y Acuicultura (PNIPA) in the category of “Investigación Aplicada y Desarrollo Experimental” (SIADE) in alliance with ANTAMINA and IMARPE.

The equipment provided by Tumi Robotics are: Two (02) maritime surface vehicles, Two (02) outboard thrusters of 2000 W input power equivalent to 5HP propulsive power, Two (02) lithium batteries of 3500 Wh at 25.2 V with IP67, Two (02) depth + RGB camera of Intel Realsense brand, Two (02) 3D lidar of Ouster brand, One (01) UAV series Matrice 300RTK of DYI brand, Three (03) GPU Jetson Nano with NVIDIA processor, One (01) GNSS+RTK of Trimble brand and Two (02) INS+GPS devices.

In Figure 1 is shown the three (03) platforms with which the tests will be carried out to validate the algorithms, electronic and mechanical systems.

Figure 1: ASV platform for testing and validation (if WAM-V is provided).

This section details the process that the WAM-V marine vehicle will undergo in order to successfully achieve all the six tasks of RobotX 2022 competition.

1. Supply and Electronic System

In order to transform the base platform into a fully functional ASV (Autonomous surface vehicle), several mechanical and electrical components should be considered: **1.1) Propulsion:** Two (02) electric thrusters are included as the main source of propulsion allowing a differential drive of the marine platform. These motors should provide the necessary power and thrust to move the vehicle with a maximum payload of 270 kg (considering a WAM-V 20) at a proper speed to let the vehicle achieve the tasks autonomously. **1.2) Power Supply:** Two (02) lithium batteries capable of supplying the power required by electrical components, sensors and actuators. Each battery is attached to each hull and paired with its own BMS (Battery management system) in order to properly monitor its state. All components of this system comply with an IP67 protection standard due to constant exposure to water. **1.3) Power Electronics:** The main objective of the system is to distribute and regulate the power delivered by batteries, so that electronic components, sensors and actuators receive the appropriate voltage level. Reverse voltage protection circuits are also employed at the input and output of the DC-DC converters to avoid damage any device. **1.4) Control Electronics:** The control electronics system is made up of three (03) embedded computing devices (one microcontroller and two GPU) capable of acquiring signals from sensors and executing the algorithms to let ASV perform all tasks autonomously. The microcontroller is dedicated to data acquiring, preprocessing (amplification and filtering) and interfacing with the GPUs. The first GPU is in charge of detecting the position of the acoustic source and autonomously control the vehicle, while the second one focuses on avoiding obstacles and managing computer vision techniques. The use of an

IP67 rated plastic enclosure is considered to protect the control and power electronics systems against possible shocks, contact with water or heat exchange with external devices. While cabling (powering and communication) between inner and outer devices can be carried out using sealed connectors and waterproof glands mounted on the plastic enclosure.

2. Signal Processing

In order to analyze the environment, the following strategies are considered: **2.1) Object detection:** A system composed by a 3D LiDAR is used for detecting and identifying the relative position of dock bays, markers and buoys. Samples points located too closed to the laser range finder, outside the working area and inside water are discriminated following specific criteria based on the distance and intensity of each sample. By this, the number of operations to be performed by the processors can be reduced. After that, a feature extraction method is used to separate the target from the environment and a classification algorithm to recognize each of the three types of target objectives. **2.2) Vision system:** This system has three main functionalities, a) object color identification, b) color code pattern identification and c) wildlife identification using a hyperspectral camera. In order to detect the color of an identified object a small area of interest is selected, then it's converted to HSV color space. Using this, the color recognition algorithm is less sensitive to lighting conditions. For color pattern identification the system waits until black color is detected for 2 seconds, then the detected colors are recorded. For wildlife identification, object segmentation of hyperspectral images based on his unique spectral signatures is used. **2.3) Acoustic Source Localization:** For the purpose of localizing the active underwater beacon, a USBL (ultra short baseline) configuration composed of three (03) hydrophones are used. Through this configuration, position of the acoustic source can be determined by measuring the range and calculating the direction by "phase differencing" method. The data measured by the hydrophones is amplified and filtered using the microcontroller in order to reduce the signal to noise ratio and improve the accuracy of the localization task.

3. Networking Design

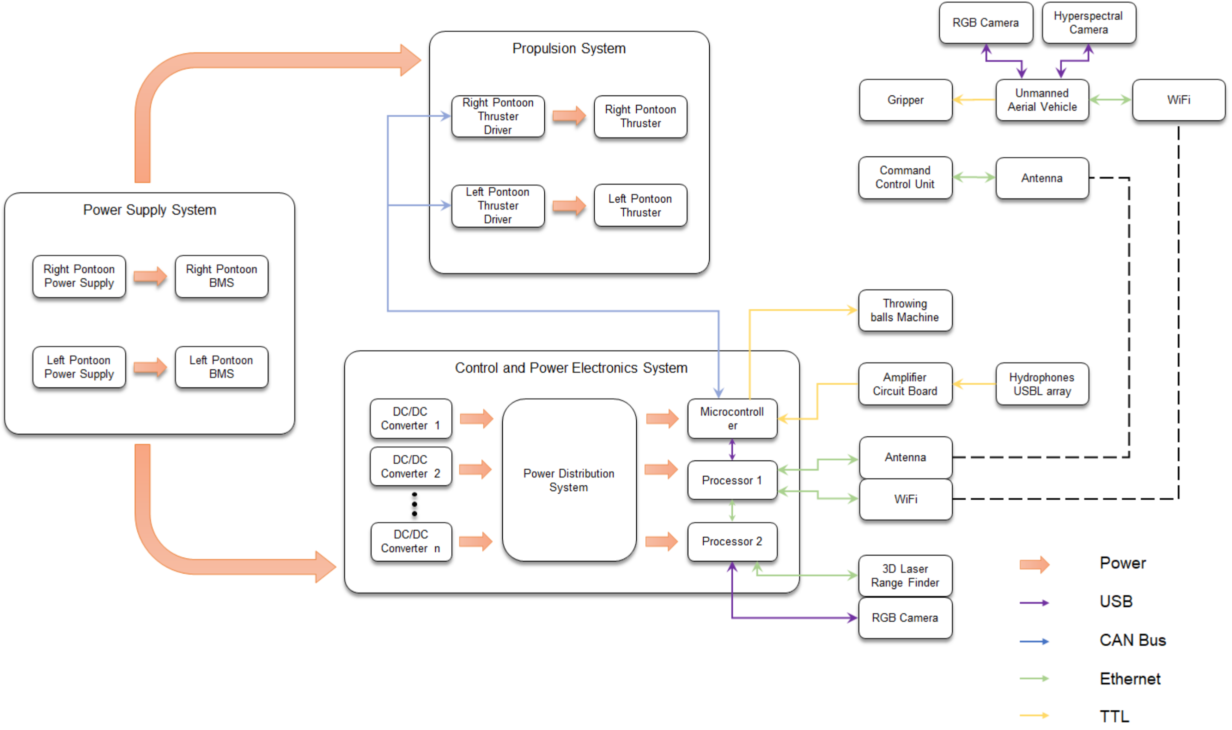

Figure 2: Network Design of Hardware Components Connection

4. Emergency Stop System

The main function of the system is to stop the thrusters when an undesired situation occurs. Emergency stop buttons are connected to dedicated pins on the motor driver controller. A microcontroller is used in order to send commands via serial communication to the motor driver including e-stop signals. The emergency stop system also consists of sending a ping signal from the base station to the WAM-V and UAV in order to set up a status signal of good performance.

5. Mechanical Systems

5.1) Attachment for positioning and throwing racquetballs: The mechanism consists of a compartment for storing racquetballs, which move them one by one through a tube to a position between two rollers rotating at high speed that are responsible for launching the racquetball. The mechanism is mounted on a mobile platform that allows it to rotate on its own axis and in a vertical axis. To take the mechanism in the correct position and regulate the power to which it must be launched, the information obtained by the vision system is used. The motors responsible for transmitting power to the rollers have controllers that allow their speed to be regulated. **5.2) Gripper for pick up colored discs:** The gripper claws to be used will be shaped to ensure three points of contact with the discs. In addition, the surfaces of the contact areas will be rough ensuring a better grip and avoiding possible slipping. This gripper will have a light and compact actuator that will allow it to be mounted on the bottom of the UAV without influencing too much on its autonomy time and maneuverability. The signals to close or open the gripper will be sent by the microcomputer of the UAV based on the information obtained by its multiple cameras.

6. UAV and landing platform

The UAV will have its own computer used exclusively for vision processing, gripper control and landing algorithm. The vision system of the UAV will follow the same procedure explained in 2.2 for the recognition of buoys and the disks colors. All this information will be used to define the route to be followed by the ASV in the different tests, so it will be sent in real time to the main computer wirelessly. The gripper control for pick up discs will depend mainly on the image processing of a camera placed at the base of the UAV with a downward direction and it will work as explained in 5.2. The autonomous landing algorithm initially uses information from the UAV cameras and the light beacon signal to approximate the location of the helipad. After moving to this location, maintaining a certain height previously defined, information from additional sensors such as infrared and ultrasonic sensors is used for a more precise landing. It should be noted that while the UAV is descending, it will correct its trajectory based on the reading of the aforementioned sensors.

7. Control Systems and user interface

The control system of the robot operates with ROS and MOOS IvP. Sensor data is collected using ROS libraries and drivers, then the data is sent to MOOS IvP in order to implement the autonomous decision-making algorithm of the robot. The graphical interface is based on MOOS and is designed to simplify the configuration parameters for the correct accomplishment of missions by the robot. Using this combination of open-source software allows the control system to be flexible and adaptable to a large number of sensors while being capable of executing complex missions.

Team Qualifications

Luis Velasco (team leader): PhD (c) in engineering, and Master in control and automation at PUCP, BSc. in electronics. Research experience (4 years) with the development of control systems for mobile robots (https://orcid.org/0000-0002-8561-4532). Professional experience (11 years) with electronics design.

Francisco Cuellar (advisor, project manager): professor at PUCP, BSc. in electronics, MSc. in mechatronics, Master in management and policies of innovation. Research and product development experience (18 years) of robotic systems (https://orcid.org/0000-0002-6661-5118).

Jorge Ramirez: Student of Master in Control and Automation Engineering and Mechatronics Engineer at PUCP (https://orcid.org/0000-0002-8155-2178). Professional experience (5 years) in developing Research Projects related to terrestrial, marine and underwater robotics.

Manuel Escobar: Student of Master in digital and image signal processing, BSc. in Mechatronics Engineering at PUCP. Research experience (3 years) in mechanical and electronic design of unmanned and autonomous terrestrial and marine vehicles (https://orcid.org/0000-0003-1112-2313)

Miguel Vargas: Student of Master in Mechanical Engineering, BSc. in Mechatronics at PUCP. Research experience (3 years) in mechanical and electronic design of marine vehicles (USV, AUV and ROV's) and automation projects (https://orcid.org/0000-0001-5891-8859).

New students: there will be an announcement for the 2021-II semester at PUCP (august) in which we will integrate two (03) undergraduate and two (02) graduate students to the team. The fields of interest are digital signal processing, computer science, mechanics, electronics, and mechatronics.

Facilities

Two (02) stages are proposed for implementation and validation. The first stage consists of a controlled laboratory implementation that will be performed at San Miguel, Lima – Perú, inside PUCP at the project's laboratory from mechatronics engineering as shown in Figure 3a. The laboratory has the necessary tools and equipment to manufacture and modify mechanical pieces, and to assemble, program and test the electronic components. The validation stage is in real field conditions, at La Punta in Callao – Perú, in collaboration with the open space at Instituto del Mar Peruano (IMARPE) as shown in Figure 3b. PUCP and IMARPE are located 11.2 km from each other (30 minutes driving). The means for transportation of the team and equipment will be provided by the company TUMI ROBOTICS.

Figure 3: a) Mechatronics project laboratory (PUCP), b) IMARPE port at La Punta – Callao.

Sponsorships and Partnerships

TUMI ROBOTICS (sponsor): provides the materials and equipment to build the propulsion, energy, and electronics and sensor systems that are placed in the WAM-V platform, and the cases to transport the equipment at national and international level. The company will compromise resources to mobilize and cover living expenses of two (02) members of the team to Sydney – Australia and cover all the logistic expenses for the equipment. (https://tumirobotics.com/).

PUCP (partner/sponsor): provides the space and laboratories, manufacturing equipment and tools from mechatronics engineering to implement and test the robotic platform. The university provides funding for high impact research projects and international mobilization of students that could cover mobilization and expenses in Sydney – Australia of at least two (02) members of the team. (https://investigacion.pucp.edu.pe/convocatorias/pucp/).

IMARPE (partner): provides the marine field to test under real conditions the robotics platform. The research institute has equipment and tools to recover the robotics system in case of test failures. (https://www.gob.pe/imarpe).

FONDECYT (sponsor): yearly they open calls that provide resources for mobilization and living expenses for researchers and students that participate in international events. This could cover the expenses of one (01) team member. (https://www.fondecyt.gob.pe/).

Management Approach

The project will be managed by Francisco Cuellar who has managed more than 30 projects funded by the government and industry. The budget is composed of monetary contribution and non-monetary contribution (infrastructure, equipment materials) that will be provided by the sponsors and partners. The project manager has experience attracting sponsorship for technology development and competitions.

ACTIVITIES									2022									
		Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
COMPONENT 1: DESIGN AND IMPLEMENTATION																		
1.1	Research and review of the state of the art	x	x															
1.2	Supply and Electronic design		x	x	x	x	x	x										
1.3	Development of signal proccesing algorithms		x	x	x	x	x	x										
1.4	Mechanical design for attachment of racquetball and gripper		x	x	x	x	x	x										
1.5	Guidance & control algorithms		x	x	x	x	x	x										
COMPONENT 2: FIELD TESTING AND TECHNICAL VALIDATION																		
2.1	Simulations						x	x	x	x								
2.2	Laboratory testing							x	x	x	x							
2.3	Field experiments											x	x	x	x	x	x	
COMPONENT 3: MANAGEMENT COMPONENT																		
3.1	Logistics		x	x			x					x					x	x
3.2	Recruitment (*)	x	x															
3.3	Public relationship (sponsorship)	x	x	x												x	x	x

* For recruitment, there will be a call for postgraduate and final undergraduate students with interest in fields of computer science, image and signal processing and control of autonomous vehicles. The applicants will go through a selection process that will consist of curricular and psychotechnical validation, as well as interviews to identify soft skills that the team requires.

Rough Order of Magnitude Cost

Expenses	Monetary TUMI ROBOTICS ($)	Non- monetary TUMI ROBOTICS ($)	Monetary PUCP ($)	Monetary FONDECYT ($)	Total ($)
Equipment	**5,000.00**	**32,578.00**	**0.00**	**0.00**	**37,578.00**
● Motor (02)	0.00	7,700.00	0.00	0.00	7,700.00
● Battery (02)	0.00	7,300.00	0.00	0.00	7,300.00
● UAV (01)	0.00	8,000.00	0.00	0.00	8,000.00
● Lidar (01)	0.00	3,500.00	0.00	0.00	3,500.00
● Depth Camera (02)	0.00	378.00	0.00	0.00	378.00
● GNSS+RTK (01)	0.00	3,000.00	0.00	0.00	3,000.00
● GPU (02)	0.00	200.00	0.00	0.00	200.00
● INS+GPS (01)	0.00	2,500.00	0.00	0.00	2,500.00
● Hyperspectral Camera (01)	4,200.00	0.00	0.00	0.00	4,200.00
● Gripper (01)	800.00	0.00	0.00	0.00	800.00
Air tickets (5 members) (*)	5,000.00	0.00	5,000.00	2,500.00	12,500.00
Living expenses (9 days / 5 members) (*)	3,600.00	0.00	3,600.00	1,800.00	9,000.00
Logistics (shipping, airfare, others)	5,000.00	0.00	0.00	0.00	5,000.00
Materials and Supplies:	**6,000.00**	**0.00**	**0.00**	**0.00**	**6,000.00**
● Electrical Components	3,000.00	0.00	0.00	0.00	3,000.00
● Mechanical Components	3,000.00	0.00	0.00	0.00	3,000.00
Overhead	3,000.00	0.00	0.00	0.00	3,000.00
Total ($)	**29,600.00**	**32,578.00**	**8,600.00**	**4,300.00**	**73,078.00**

* Expenses distributions are according to the covers mentioned in “**Sponsorships and Partnerships**”.

Summary

The present document is a brief resume of how the team will approach the project implementation and validations. The team members have previous experience in project development and implementation of robotic systems.

The majority of the team members are already developing an autonomous USV: “Implementation of an unmanned catamaran USV for real time monitoring of oceanographic parameters and marine ecosystem in the coastal area of Huarmey”. PNIPA - Applied Research and Experimental Development (SIADE) 2018-2019 ((PNIPA-PES-SIADE-PP-000177, budget USD 200K), which is developed by TUMI Robotics in collaboration with IMARPE and PUCP. Various expensive equipment and materials could be used in the WAM-V platform, and then most of the time of the researchers and students will be used in the integration of components and algorithm development.

We already have experience with international competitions, participating in the World Robot Summit 2018 in Tokyo – Japan, Plant disaster prevention contest. And then, the logistics required to move personnel and equipment is dimensioned properly. We expect that at least five (05) team members will travel to Sydney – Australia.

In conclusion we have the team with validated experience in the development of this type of robot technology, and we will transfer the knowledge to a new group of students that will join the team. We have top of the line equipment and materials to bring to reality a robust solution for high performance in maritime environments. The monetary resources for logistics of personnel and equipment to Sydney will be covered by an industrial sponsor (TUMI Robotics), academic partner (PUCP), and government sponsor (FONDECYT).