X-Robot WIP: An Undergraduate Research Experience on Autonomous Robotic Systems

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Abstract– This work-in-progress (WIP) presents the research experience of undergraduate students on unmanned vehicles at University of Puerto Rico-Mayagüez. As part of this WIP, an unmanned water vehicle (UWV) prototype will be designed, manufactured and programmed by undergraduate students with the intention of being cost-effective and environmentally friendly. After the development of a successful prototype, the larger scale model will begin development, which will be presented at the Maritime Robot-X Challenge. Potential applications for the designed UWV are in homeland security, defense, natural disaster assessment, among others.

Keywords—engineering education, prototype, cost-effective

I. INTRODUCTION

Automated robotic systems are becoming more of a reality each day. With an increase in people's needs, engineers are coming up with better ideas to improve them each day [1]. Autonomous robots have been a leading topic in the science and engineering community, do to their immense social impact pervading all areas of society including medicine, transport and manufacturing [2]. These machines are capable of performing from the most mundane task to the most complex by themselves, without human aid. For instance the insurance Institute of Highway Safety (IIHS) has been working for the last two years on a system capable of warning drivers if they are drifting or are close to coming in contact with another vehicle [3].

This rising field will bring together worldwide leaders in robotics and autonomous systems across academia, industry, and government to scope the long-term vision and challenges in this rapidly developing fields. Already many organizations are developing new ways to broach the subject of autonomous robotic to future generations. The Association for Unmanned Vehicle Systems International (AUVSI) Foundation is a non-profit educational foundation dedicated to introducing students to hands-on robotics activities. One of the foundation's primary missions is to develop future scientist and engineers focused on robotics to facilitate interaction between academic community, government and industry. In 2012, the AUVSI foundation and the U.S. Office of the Naval research (ONR) collaborated to launch the biennial Maritime RobotX Challenge. Through this competition the ONR aspired to reach regional partners around the Pacific Rim while creating a new high-level competition focused on autonomous surface vehicles platforms and sensors [4]. This competition will aid the research and development for an unmanned Water Vehicle (UWV) to solve problems such as environmental disasters, homeland security [8], etc.

This research project is done by the undergraduate students at University of Puerto Rico- Mayaguez (UPRM). It consists of creating a prototype of an UWV with the purpose of later creating larger scale model that will compete in the RobotX challenge. Even though there are similar research projects to this one, this concept goes much further than simple data and research collection. Other Projects in UPRM are based on a remotely operated vehicle (ROV) system [6] while this one is completely autonomous. This makes its innovative capabilities much larger in comparison. Therefore this research project has more complex coding, considering all the different components that must be operated autonomously. Its design is also a lot more elaborate because it requires different structural Analysis and a fluid analysis to reduce as much drag as possible.

The purpose of the prototype is to focus mainly on the software development of the UWV that will be used in the competition. The manufacture of the prototype will be managed with a limited budget, considering the financial situation; the materials and components that were chosen are based on cost effectiveness and simplicity. The model will resemble a small catamaran. The electrical components, such as the battery, motor, motor shield, will be chosen based on the design of the water vehicle created. This prototype can later be used in outreach programs to reach out to high school students and spark an interest in robotics and other STEM fields throughout Puerto Rico.

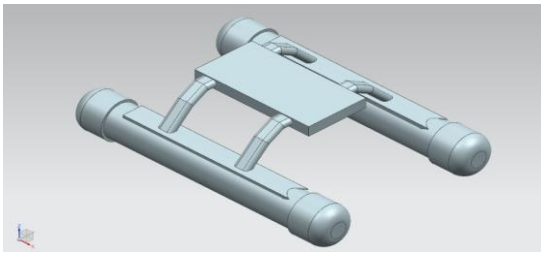

Fig. 1: X-Robot prototype MK. 4 Isometric View

The software development is crucial due to the high level of image processing and navigation skills the UWV will need to have in order to succeed in the RobotX competition. The competition consists of creating a complex autonomous system that can identify and classify different symbols and objects, adapt to dynamic environments, make smart decisions and the ability to priorities tasking based on mission time to accomplish the overall mission.

II. MATERIALS AND METHODOLOGY

The mechanical engineering students participating in the project will focus on the design and manufacturing of the bodies of the UWV, which will be capable of withstanding the static and dynamic loads that the systems will experience depending on the application. The electrical engineering students will concentrate on the integration of the mechanical and electronic components (i.e. brushless DC motors, servomotors, battery, microprocessor, infrared sensors, etc.) to the bodies of the robotic systems. The computer-engineering students will focus on giving each robotic system the capability of autonomously carrying out specific tasks via the programming of the microprocessors.

A. Manufacture and Design

The structure of the UWV must be capable to withstand its own weight and the added weight of all the electrical components. These loads will be static and the dynamic loads will come from the forces applied to the body by the environment. To simulate these conditions, Star CCM+ and Ansys will be used to optimize the robot's performance. Manual calculations will also be conducted for further result analysis and comparison. Star CCM+ will help to build the most cost effective and aerodynamic structure as possible by performing some fluid dynamic testing. The mechanical engineering students will also collaborate with the electrical engineering students in the acquisition of the mechanical components. A decision matrix (Table 1) was established for certain materials to manufacture prototype. The following materials were chosen based on research conducted considering a low budged and a simple design [7]. Other factors were also considered like buoyancy and density keeping in mind the prototype must be able to float.

B. Software Development

The computer-engineering students will focus on giving each robotic system the capability of autonomously carrying out specific tasks via the programming of the microprocessors [8]. The main purpose of the software is to identify objects and avoid collisions and implement autonomous driving. The sensors will use open CV for the image processing in order to program the Raspberry Pi with Java programming language; java works well with the Raspberry Pi due to the performance advantages it offers compared to other object-oriented languages. The Arduino will allow the robot to control the movement and to transmit the entire sensors signal to the main controller with C programming language. One of the main reasons that Pure C programming language will be used is because of its benefit of memory economy. That way, it will conserve memory space and prevent the robot from being overloaded and optimize the time of processing the data. At the moment infrared sensors are also being deliberated due to the fact that there would be less interface in comparison to sonic sensors that could be easily deviated due to tides, which could deviate the robot itself.

C. Motors

One of the most important components in the X-Robot prototype is the motor. To move it, the X-Robot will have two motors on its rear. After analyzing the specifications that the two motors should have, it was concluded that the best option for a water vehicle should be waterproof motors. The weight of the motors was an important factor to consider because the lighter they are, the easier it will be to control. For this reason a brushless motor was chosen over a brushed one due to its small and light structure furthermore brushless motor can do the same work as a larger brushed motor [9]. The T100 Thruster was chosen in behalf of being waterproof and having a propeller preinstalled. The T100 Thruster comes with Electronic Speed Controllers (ESC) and will be controlled with an Arduino [10]. Simulations on algorithms to control the motors will be developed using Matlab and Simulink. The reason is that now Matlab has developed hardware-on-the-loop tools using Simulink. Providing to the student a unique experience on the use of state-of-the-art tools related to robotics, programming, and embedded systems.

Table 1

Example of selected materials for the X-Robot Prototype

Materials	Cost per lb./in^3	Elasticity	Buoyancy	Yield Strength	Ultimate Tensile Strength	Density	Corrosion	Total 35
Aluminum 6061	4	2	3	2	2	3	3.5	19.5
Cast Iron	3.5	2.5	1.5	2.5	2.5	1.5	1	15
Steel Alloy	3	3	1.5	4	4	1.5	4.5	21.5
Stainless Steel	3	3	1	3	3.55	1	4	18.5
Fiber Glass	2	5	5	5	4.5	5	3.5	30
Carbon Fiber	Pending	4	3.5	5	5	3.5	5	26
PVC	Pending	1	3.5	1	1.5	3.5	2	26
Wood	Pending	0	Pending	Pending	Pending	Pending	N/A	Pending

Table 2

Example of Gantt Chart: Timeline for RobotX Prototype

Tasks	Jan.	Feb.	March	April	May	Summer
Acquisition of Materials for Prototype						
Manufacture of Motor Shield						
Manufacture of Prototype						
Development of Software						
Motor Mounting						
Test and Validation						

III. SKILLS TO BE DEVELOPED

The expectation in the proposed X-Robot Autonomous Robotic System research project is that every student member develops different skills in areas such as robotics, design and control systems, by using common software such as Matlab, NX or SolidWorks for design, or by using basic assembly tools for the confection of components. Also, by working in a group environment composed of different engineering branches, they'd be acquiring, not only engineering skills, but the ability of effective communication, as well as gaining teamwork, leadership and research experience. There are some basic skills and knowledge that the students participating in this project will master. Some of these skills are general to all projects, such as good communication skills and teamwork. Finally, the Table 2 shows the Gantt Chart that the students use for time managing skills during Spring 2017 for a successful project.

IV. FUTURE WORK

For future plans, once the RobotX prototype is manufactured and tested successfully it will be presented around schools in Puerto Rico in order to involve the young community in robotics. The larger scale model, besides being presented in the Maritime RobotX Challenge, could be used for homeland security, natural disaster assessments and for military purposes. At the moment the U.S. Navy's Office of Naval Research (ONR) has announced that it has recently tested autonomous unmanned swarming boats in a demonstration, with results that show new possibilities for autonomy in future naval missions.

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