Journal Paper for East Los Angeles Robotic Huskies

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I. Introduction

East Los Angles College was new to the Robosub competition last year. This year the Robotic Huskies created two possible designs for a fully functional autonomous underwater vehicle to compete in this year's competition. The first design was Paco 2.0 a designed that improved what worked last year for the team, but taking what was learned to make Paco 2.0 a more effective autonomous underwater vehicle. The second design that the Robotic Huskies created was ambitious. The second design is Called crush and it was the mission of crush to look much more cohesive and dynamic. It was the goal throughout the year to be able to design, construct and program both Paco 2.0 as well as Crush to be able to complete all the challenges put forth at the 2017 Robosub competition. It is the goal of the Robotic Huskies to have their member gain technical, mechanical, and programming experience through building and designing Paco 2.0 and Crush. To enhance the ability of team member s in every one of these facets the club held workshops throughout the year. The Robotic Huskies will continue to learn and build from the experiences at the 2017 Robosub competition and implement those lessons for future club members to build off of.

II. Design Strategy

The design strategy this year for the Robotic Huskies was aimed at designing two fully functional autonomous underwater vehicles. With the knowledge that was gained from the 2016 Robosub competition it was the ambitious goal of the team to create a design that improved the design of last year's AUV into Paco 2.0. Since Paco was fully functional and was very successful last year the goal was to improve certain aspects of the design but not change the inherent framework. Mechanically Paco 2.0 works the same way as Paco did. Paco 2.0 was to be the reliable AUV that would mechanically perform with-out fail though it may lack certain complex dynamics that Crush was designed to incorporate.

Crush was a new design that built off the basic frame work of Paco but was more efficient and more dynamic. Last year Paco was now equipped with all the components necessary to complete all of the obstacles. The focus was to enhance our end product with and autonomous vehicle that was fully functional and could complete every one of the obstacles.

III. Vehicle Design-Mechanical

A. Paco 2.0

The AUC that compete in the 2016 Robosub competition was the first of its kind for East Los Angeles Robotic Huskies. The final design and product was the result of more than two years of debating which design would not only work best but be the most realistic to build with the budget that was set to the Robotic Huskies. Paco 2.0 successfully incorporated all the components that had worked for the 2016 Robosub Competition. In order to keep the motherboard, batteries, bread board, and the rest of the electronic components safe from the water Paco 2.0 has a hull that is the Pelican 1500 case made from ABS plastic. The Pelican 1500 case is dependably water tight up until approximately 15 feet of depth. These specifications were perfect for what is required of Paco 2.0. One of the major problems witnessed at the 2016 Robosub Competition was the buoyancy of some of the AUVs. Given this knowledge the Pelican case was perfect to avoid this problem because it provided 50 pound of buoyant force. For Paco 2.0 an extruded aluminum frame was used for its durability and its light weight. The Pelican 1500 case hull is attached to the REV Robotics 1-inch extruded aluminum purchased from AndyMark.com. The rest of the external components including the claws, torpedoes, the forward facing camera and bottom facing camera, as well as the dropper are all attached to the extruded aluminum frame of Paco 2.0. The hull was faceted onto the frame so the clasps of the hull sit approximately a half an inch above the top of the frame also giving an allowance from the edge of the hull to the beginning of the frame to be approximately 1 inch. The frame and the external components are held together by #10-32 x 3/8 screws and #10-32nylock jam nuts. There was much debate about completely changing the type of transportation that Paco would use to be able to get around above water. Some of the options that were discussed was an almost tank transportation system that could lead Paco 2.0 directly into the water, as well as created a completely external transport system that Paco 2.0 would be put into and then taken to the desired location. The cost of both of these options would out way the benefits. The conclusion was drawn to have four wheels at each corner of the frame, the same wheel system as Paco, which added a height of 3.5 inches off the ground protecting the lower external components and when a "leash" is attached to the top two corners of Paco 2.0 makes transporting the AUV much easier than other methods.

Fig. 1. Early Solid Works rendering of Paco 2.0

B. Crush

Given the reliability and availability of the design and resources for Paco 2.0, it was the aim for Crush to be much more innovative, unique and dynamic in composition and application potential. It was apparent from completing last year's competition that the Robotic Huskies as a whole needed a more cohesive understanding of every aspect of an autonomous underwater vehicle including: electrical skills, mechanical skills, and programming skills. In order to achieve the enhancement of these skills prior to jumping into designing Crush it was the goal of the robotics team to hold workshops for the team as well as any other students who wanted to participate, in order to increase the knowledge set of every individual. It was a strategy that had basis in the theory that if every individual's knowledge set expanded then there would be more probability in success of the design and creation of the new autonomous underwater vehicle. There were a number of stages in discussion with regards to Crush. The team used the successes of the design for Paco 2.0 and used that as a platform for designing Crush. Crush was to fix the problems that Paco experienced in testing and in competition. Thought the Pelican 1500 hull was effective up until 15ft, at around 13 feet the hull would begin to compress under the pressure creating possible leaks on the sides of the hull. Given the Irony to the name Crash the new design had to be strong and sturdy underwater with more allowance of depth. Crush was designed with a custom hull as well as the implementation of a leak sensor to make sure no water was entering the hull. There were three options for the custom hull:

1. Extruding the hull from a block of Aluminum. This would ensure not only near guarantee of a water tight hull to a much deeper depth at well as strength and being sturdy.
2. Getting specific cut pieces of sheet metal and welding to pieces together in the dimensions that were stated for the hull.
3. 3-D printing a mold of the entirety of the hull and sending the mold out to different resourced in order for that mold to be used to cast a metal version of the hull.
4. To order polycarbonate tubing and using a lathe to create the necessary dimensions.

All of these options had their positive and negative sides. Ultimately the largest contributing factor was the cost of each option. The cost of the first three options would be between 4,000 all the way up until 10,000 dollars which would be the majority of the budget. It was concluded that fiscally the most realistic option was the polycarbonate tubing. The tubing's specifications were perfect for what we needed at a fraction of the cost of only 500 dollars for 5 feet of the tubing. Below are some rendering of the different designs that were discussed.

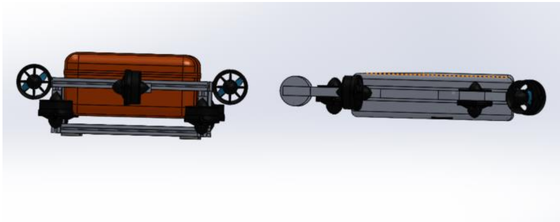

Fig.2 Early comparison renderings of Paco2.0 and possible Crush design.

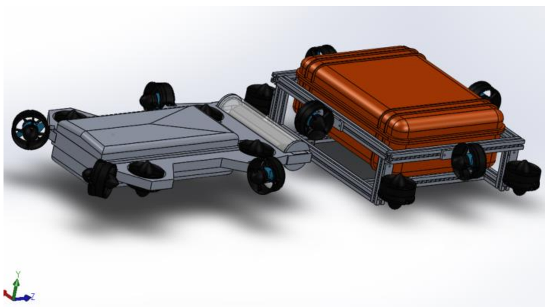

Fig. 3. Isometric view

Unfortunately due to budget and time restraints the design and creation of crush will be a goal of next year's robotics team. It was ultimately decided that Paco 2.0 held the highest chances of being completed and competition ready. Therefore Paco 2.0 design was picked to be the competitor in the Robosub 2017 competition.

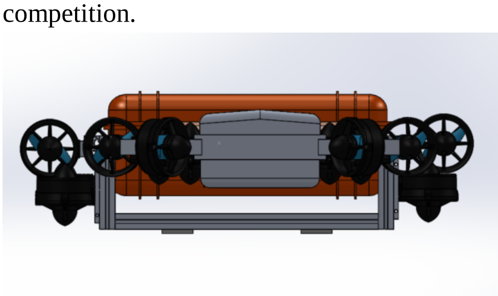

Fig. 4. Frame, thruster, and hull rendering for Paco 2.0

C. Hull Penetrators

Paco 2.0 used a Pelican 1500 case that was sturdy and waterproof but all allowed the team to drill holes in it in order for the external components to be able to connect through the hull. The team used both 3and 8-pin Sean Con Bulkhead Penetrators purchased from Crust Crawler.com. By using these penetrators the team knew that they would keep the electronical components water safe all while still being able to transmit electronic signals necessary for the full functionality of the external components. These hull penetrators also gave way to the possibility of changes without having to drill anymore holes into the hull. The camera enclosures however used a more permanent hull penetrator from Blue Robotics. These were used at the camera enclosures because the permanency of the placement of the cameras and therefore to necessity to be able to disconnect them and reconnect them was not pertinent.

D. Grabber Design

The claw design was one with so many possibilities that the team spent a lot of time discussing and trying to create a claw that would be the best underwater. At one point throughout a number of team meetings there was an all-out design brain storm on the white. Any team member who had even the slightest input on how to design and or construct the claw got up and drew their idea on the board. After a decent amount of time the designs were narrowed down and voted upon by the entire team. The conclusion was to use a claw design that was found on www.thingiverse.com/thing:1480408 with the title Mantis Gripper. Though this was not designated to be a claw used for underwater use the team made modifications to it in order for it to be able to be used. The claw's STL file was downloaded from the website and was modified using Solidworks 2015 3D modeling software. After the claw was modified to better suit the environment it was going to be used in, the team 3D printed the claws using PLA plastic on a MakerBot Replicator and then a silicone mold was made that was attached to the inside of the claw in order for it to more efficiently grip underwater. While constructing the claws themselves the washers and bolts unfortunately seemed to become loose very soon after testing the individual claws. The solution to this was remedial but did the trick; it was to actually glue the washers and bolts down.

The first claw was mounted easily by using a metal bracket on the extruded aluminum frame on the front of the AUV. The claw that was intended on sitting vertical was more of an issue as is would scrape the ground if mounted with the same method the first claw was. In order to solve this problem the vertical claw was made retractable using a spring system. Both claws were connected to waterproof servos in order to perform the tasks the AUV needs to complete in the obstacle course.

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Fig.5. Forward facing claw.

Fig.6. Vertically mounted claw

E. Torpedo

While coming up with a torpedo design it was an open floor brain storm. It was encouraged for any ideas no matter how out there to be suggested. Suggestions for the torpedo ranged from a Mentos being dropped into some type of miniature canister filled with soda to propel it to more realistic ideas, such as the one implemented like Carbon Dioxide propelled torpedo. The design of the actual torpedo was modelled after the dynamics of submarine torpedoes in order to attempt to achieve maximum propulsion and thrust. The actual torpedo is made from a ¾" PVC pipe, a 12 gram Carbon Dioxide cartridge, three 3D printed fins and a3D torpedo head. All of the 3D printed components were designed and created on Solidworks and printed using PLA plastic using the MakerBot Replicator 2. The concept is that the CO2 cartridge will be based inside the torpedo and on the other end of the housing unit for the torpedo a spring loaded mechanism sits and will strike a pin into the CO2 cartridge. Once the servos get the signal to strike the cartridge with pin the cartridge once punctured causes the pressure to build up between the torpedos itself and the housing unit. Once the pressure has reached the maximum level it will cause the torpedo to propel forward. This will continue until there is no longer any Carbon Dioxide left in the cartridge. It is the design and goal of the 3D printed fins and torpedo head to guide the torpedo along a straight path towards the targets.

F. Cooling System

Last year the team witnessed another major issue at the 2016 Robosub Competition, and that was over heating issues. Many teams had over heated their entire systems as well as their thrusters. The thrusters purchased from blue robotics with the escs built in overheated in the intense sunlight of the competition. It was the intention of the thrusters to be used only underwater so that the water would cool the escs but when teams would test there thrusters outside that waster in combination with the intense sun the escs overheated very quickly and left the teams in a predicament. Luckily for the Robotic Huskies overheating was not an issue for us. The electrical head and the rest of the team came up with a very efficient method of cooling the system down. Overheating was a real concern given that all the heat being produced inside the pelican case would no new air to be able to circulate it. One option that was discussed was to have a fan on the top of the Pelican to circulate as much air with in the case as possible. This option was quickly dismissed because it was decided that this would not be enough to keep the system cool. Circulating air that is continuously rising in temperature would not ensure a low temperature of the system. The second idea that was mention was to somehow use the sea water that would be in the pool to cool the processor or help the air cool down somehow with in the hull. This was also dismissed because it added a complication to the design process which would be the necessity for a filter for the sea water that was used in cooling the system. There would be too much of a possibility of contamination of the entire cooling if there was an efficient enough filter being used. After the two first possibilities and discussing some possible other option it was decided to use a sealed loop concept to cool the system. To take the heat created by the processor out, the sealed loop system used soft lined tubing and constantly pumping distilled water. This incorporated a heat sync on the outside of the hull connected to hard line copper piping. Copper piping was chosen because of its cooling benefits. The hot water streamed through the soft tubing is then streamed through the hardline copper piping to efficiently cool it down even further. Though through discussing how many heat syncs would be necessary seemed to reach almost 6, but it was then though that once the AUV was fully submerged underwater the temperature in conjecture with the heat sync, copper tubing, and sealed loop concept was more than enough.

G. Electrical Dynamic

The electrical design for Paco 2.0 was intended to be kept simple in order for any team member to be able to make the proper connection to make Paco 2.0 fully functional. It was realized at least years competition that only one of two member truly knew how to completely connect all the electrical components of the AUV in order to make the drone fully functional. The team incorporated Blue Robotics TSYSO1 temperature sensor as well as a Blue Robotics MS5837-30BA depth sensor. Recently a gyroscope was purchased and will be implemented before the competition. The hardware includes an Intel i5 processor at 3.5 GHz with 4GB of RAM and a 64 GB Solid State Drive. In order to efficiently power Paco 2.0 there is a custom power distribution board, two 10 amp/hr. batteries with the option to power through a 40 amp server power supply provided by an SLA battery.

H. Camera and enclosure.

It was early on in the design process that it was decided that a web camera would be used for our cameras. The design of Paco 2.0 called for two cameras one on the front of the AUV and one on the bottom of the AUV. At first the team deemed PCV piping enclosure made with Plexiglas with the proper cement to be efficient. However, after testing these enclosures at different depths it became clear that these enclosures would not hold up in the competition and would not keep water away from the cameras. The final enclosures that were used for Paco 2.0 were machined aluminum casings to the dimension that was necessary. It was also decided that top tops to these enclosures would be threaded. The tops would have a circular space for Plexiglas to be cemented in properly along with marine epoxy. After this modification were made and implemented the camera enclosures were tested and deemed water tight.

I. Thrusters

After doing a great deal of research on which thruster would be sufficient power wise and budget wise it was decided that Blue Robotics provided thrusters that fitted the needs of the team the best. There were two T200 Blue Robotics positioned horizontally at the midpoint of the extruded aluminum frame in order to command the forward and backward control of the AUV. There were an additional six T100 thrusters from Blue Robotics mounted at the midpoint of all four vertical extruded aluminum edges of the AUV as well as at the midpoint of the two shortest horizontal extruded aluminum pieces of the frame in order to control the rotation and right to left movement of the AUV.

J. Software

Two parts of the robot are programmed: The Arduino microcontroller and the motherboard. The microcontroller is basically the "bridge" between the motherboard and the electronic components such as thrusters and sensors. The motherboard and the Arduino are connected with a USB cable so that they could transfer data via the serial port. We designed a data transmission protocol, reducing the commands transmitted to the Arduino for performance by caching the state of Arduino in the motherboard's memory.

The motherboard is the "brain" of our robot. It has a Linux operating system. It reads the data from cameras and sensors, and determines what move to perform. The most complicated job the motherboard does is to process the images. It determines the white balance according to the input image and deals with some interference factors. After that, it recognizes the target image by multiple techniques including machine learning. Other than determining where to go, the motherboard also makes plans on how to move to the target. It integrates sensor data to stabilize the robot and when without visual aids, it would be in the inertial navigation mode

IV. Experimental Results

IT was extremely beneficial to the team to have competed in the 2016 Robosub competition. Not only did the team learn what worked for them overall but they got to witness what the major problems other teams had come across during their process. Starting in January the team began water testing Paco 2.0 by submerging him in the college's swimming pool. Initial testing was done just at different depths to ensure that hull was not leaking and to try and find the maximum depth before slight failure occurred. It was concluded that the hull was still strong and water tight as deep as 13 feet. Once the AUV start to go deeper than that it, was visually obvious that the pressure from the water was too much for the hull to handle safely. The approximate depth safe for the Pelican 1500 hull is 15 feet deep.

The second stage of testing was done as often as possible in one of the team member's pools. With the AUV being powered by itself with the two 10 amp/ hour batteries and tethered in order record all the data possible the maneuverability of the AUV was tested with an Xbox 360 remote control. At this point in the testing process vehicle is not yet autonomous. This testing was done in order to check how all the thrusters were operating. At each point throughout the testing process, the team came up with a check system to ensure the hull was completely closed each and every time the vehicle was going to be put into the water. There was a two person and perimeter check of the hull every time the vehicle was to be put in the pool. The buoyancy of the drone is not neutrally buoyant but with the power of the T200 thrusters the vehicle can be kept at a consistent depth in the water and then easily remerge when necessary.

VI. Acknowledgements

The Robotic Huskies are very fortunate to have support from a number of different outlets; each one has truly helped the Robotic Huskies to execute the vision for the AUV.

From East Los Angeles College:

- The Engineering and Technologies Department
- The Associated Student Union (ASU)
- The Kinesiology Department
- ELAC Athletics
- ELAC Plant Facilities
- ELAC Community Services

Montebello Unified School District

- CTE Pathway

From Local Industry:

- LEABBS and Jose Luis Solano
- Romakk Engineering
- Blue Robotics
- CrustCrawler Robotics

VI. Appendix- Outreach Activities

The robotics team has been involved in numerous community outreach events over the years. Over the past years the robotics team volunteered for Engineering Fundamentals, which is a student led outreach program aimed at eight to twelve year olds to gain a larger skill set in the fundamentals of engineering. Some of the concepts taught and applied in Engineering Fundamentals include electrical, pneumatics, mechanical and programming. Along with outreach aimed at the younger STEM generation the robotics club held numerous workshops for fellow students. At the beginning of the school year the robotics club held numerous soldering workshops for any students who wanted to improve their skill set. Electrical workshops were also held focusing on the basic concepts of electronics.