Ambitious Axolotls

Technical Document

Estrella Mountain Community College
Avondale, Arizona

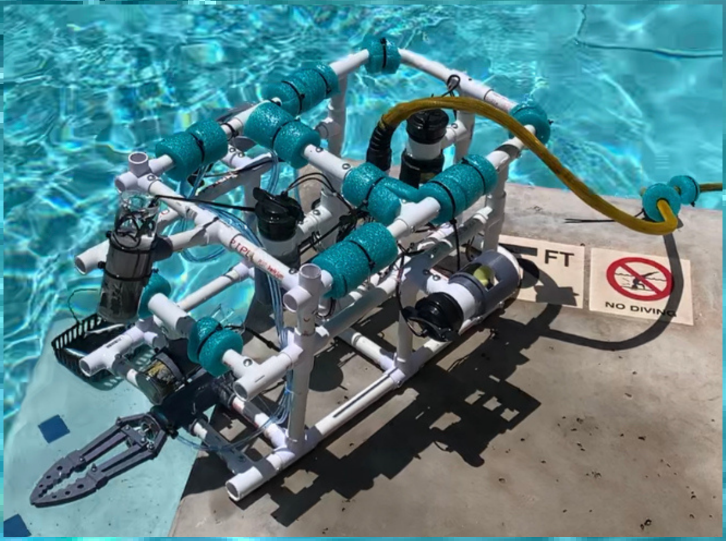

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Table of Contents

Abstract

This technical report describes the design, construction, and operation of the remotely operated vehicle, *ROV Buggy*. The *ROV Buggy* was designed and created by the Ambitious Axolotls of Estrella Mountain Community College (EMCC) in Avondale, Arizona. An axolotl is a type of salamander that is unusual among amphibians because it becomes an adulthood without undergoing metamorphosis. As a result, the axolotl remains fully aquatic and uses gills to breathe. The axolotl is native to only a few lakes and canals of Mexico city and was revered by the Aztecs as a god.

For the pst year, the Axoltls met once a week to brainstorm, construct, and test and redesign *Buggy*. The ROV was constructed with the primary goal of documenting underwater ecosystems, including taking samples of coral and performing task key to the blue economy, including installing floating solar panels and wind turbines. A detailed description of *Buggy's* key components, includes: the frame, thrusters, and control systems. In our first year participating in the MATE competition, the Axolotls focused on building a basic ROV that provides essential functionality for exploring, documenting, and completing key missions in a variety of underwater environments.

Readers will learn the challenges encountered during the construction and operation of the ROV, as well as the testing results. The Axolotls have prioritized safety - each member has been trained to use equipment and conduct themselves appropriately in the working environment. Overall, the report demonstrates the potential of basic ROVs in documenting and exploring underwater environments and showcases the dedication and skill of the Ambitious Axolotls in building and operating the ROV through a year-long process of brainstorming, prototyping, constructing, revising, and finalizing.

Design Rationale

Buggy's **frame** is constructed of PVC pipe in a rectangular and oval configuration. PVC is a familiar, accessible, inexpensive, and strong material that is excellent for constructing an ROV. PVC can be modified with heat, which allowed the Axolotls to curve potentially hazardous sharp edges from *Buggy's* frame. PVC also allowed us to efficiently design and build simple frames as models that served as prototypes for our final design.

Thrusters purchased from SeaMATE are situated central to the body of the frame. The thrusters can be connected to PVC fittings and were easy to integrate into *Buggy's* frame. Thruster shrouds were designed using the CAD software Fusion360 and Inkscape for a custom fit over the PVC connectors of the ROV's thrusters.

Two vehicle backup **cameras** are stationed at the center and top of the frame to provide underwater video. One camera is positioned facing downward to view the claw at the end of the manipulator arm and objects below the ROV. The other camera faces forward for a wide field of view in front of the ROV for navigation. The Axolotls chose to use backup cameras for their small size and wide field of view (170°).

The **manipulator arm** consists of a pneumatic actuator with a cylindrical stroke, rotary lever hand valve, hosing, and a 3D-printed claw. The Axolotls went with a pneumatic system that operates off compressed air based on prior research. As a new company and first-time competitor in the MATE ROV competition, the Axolotls took inspiration from previous models of ROVs and tried to build a simple manipulator that would integrate well into *Buggy's* structure and have short operational training for the ROV pilots.

Buggy's piloting is done with a dual joystick **control box**. The control box is used to maneuver the ROV and provide a live feed via the cameras. This helps with portability and troubleshooting since the majority of electronics are located in one central piece of equipment.

Frame

The frame of the vehicle went through three major design stages. The material of the frame, PVC pipe, stayed consistent from start to finish. The first design of the frame was a large rectangular prism that would fit within the launch station (Fig. 1). The early stages of the design focused on providing enough room to add on any desired electronics, sensors, and tools while maintaining flexibility for the position of the thrusters.

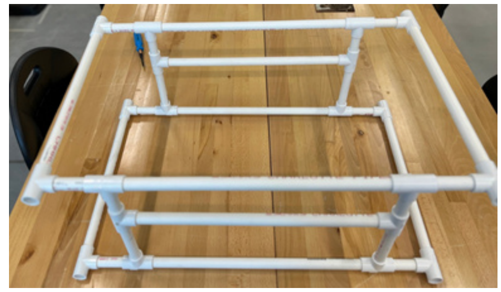


Fig. 1. First frame design

The first major change in the frame design was to reduce the length and width of the rectangular prism and curve the outer edges of the frame. This allowed the Axolotls to reduce the amount of PVC connectors required to keep the structure together. The new design also increased the speed *Buggy* traveled by reducing the overall mass of the vehicle and allowed for better control of movement as a result. The rounded edges of the frame helped reduce the possibility of damage to both the vehicle itself and the environments it encountered.

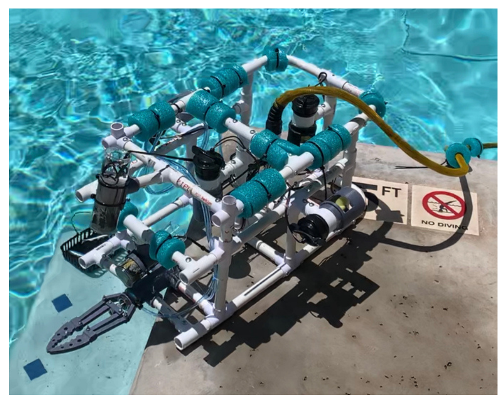


Fig. 2. Final frame design

The final design maintains the rounded edges but reduces the length, height, and width of the vehicle (Fig.2.). These changes were made to address transportation, speed, and piloting concerns. This design fits all the necessary components while giving *Buggy* the optimal speed and maneuverability possible. The ROV now travels more efficiently because it takes up less space and is lighter to carry. The smaller design makes piloting sharp turns and tilts smoother. Tasks such as installing solar panel arrays and identifying marine life are achievable with the compact, lighter frame design.

Controls

The Axolotls outsourced their control system. After team discussion, it was deemed a longer research period than the project time allowed to build a control system from the ground up. Therefore, a Barracuda kit was obtained from SeaMATE and the control system was constructed to their specifications. Some original troubleshooting ideas were necessary even though the control system was outsourced. For example, a power check showed correct wiring of the backplane panel. However multiple attempts at crimping on connectors that attached to the power switch were unsuccessful. This ultimately required a lengthening of the #2 wire and use of a connector that accepted a wider wire gauge. This allowed sturdier wire-to-connector connection for repeated backplane removal.

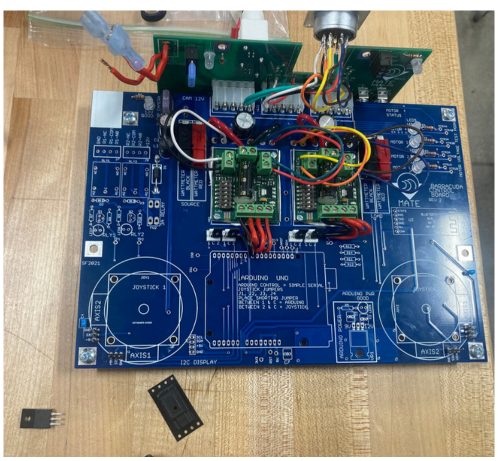


Fig. 3. Control Box Circuit Board

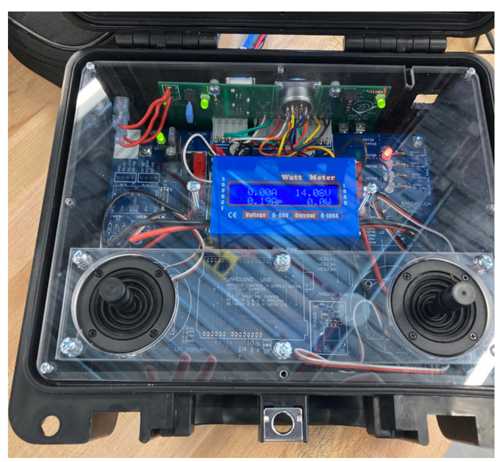


Fig. 4. Completed Control Box

Manipulator Arm

Buggy is equipped with a manipulator arm that operates using compressed air. The arm has a cylindrical stroke and the claw operates in an open/close manner. The inspiration for the final claw design came from thinking about the claws of crustaceans like lobsters and crabs and other manipulator claws from our research (Fig.5). Earlier designs were more akin to a claw machine game's design (Fig. 6) but it was decided the two "hand" claw was better suited for the small items manipulated in the competition missions.

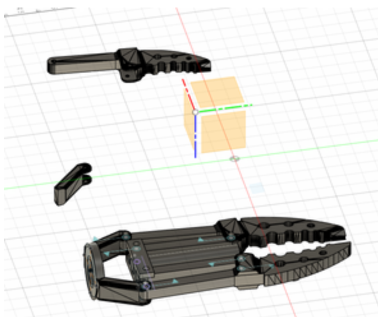


Fig. 5. Crustacean inspired claw. Allows a larger variation of grip for different objects.

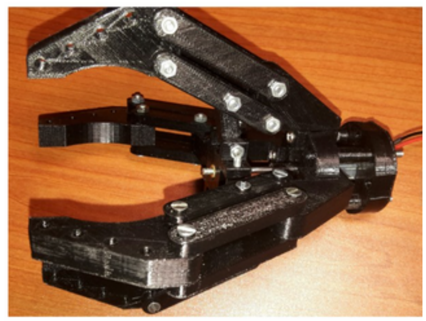


Fig. 6 Test design of a four arm claw.

There was debate of whether the arm should be powered electronically or pneumatically. Ultimately, the team decided to go the pneumatic route. This removed problems around power consumption and gave way for a valve controlled stroke to be implemented. Rotating the handle of the controller clockwise opens the claw and rotating the controller counterclockwise closes the claw. There is also a neutral setting on the controller that keeps the claw in its latest position by restricting airflow through the attached tubing. The claw attachment was modeled in the CAD program Fusion360, 3D printed, and bolting the pieces together. Hot glue was used to help enhance the grip of the claw and prevent overlap when closed.

Fig. 7 Test design for an electric claw

Fig. 8. Pneumatic claw and controller

Propulsion

Buggy's thrusters are positioned to capitalize on the specifications of its control box. It especially has a smooth yaw left and right control. The thrusters for longitudinal direction are positioned interior to the vehicle, closer to the center of gravity. The thrusters that control latitudinal direction are positioned exterior to the body. When testing different thruster positions, the Axolotls made a note of how much power they were consuming in the screen in the middle of the control box (Fig. 9). The final configuration (Fig. 10) maximizes control and minimizes power consumption during operation.

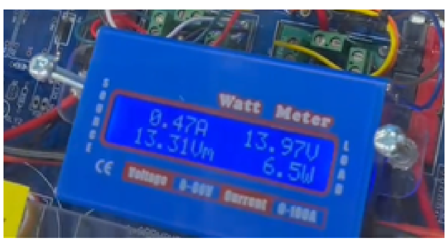


Fig. 9. Control Box screen displaying real time power consumtion

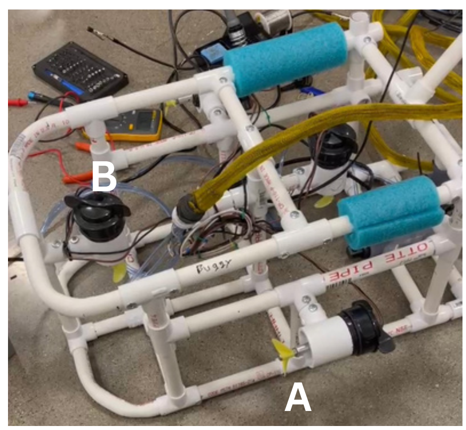


Fig. 10. (A) Latitudinal thruster (B)Longitudinal thruster

Safety

The Ambitious Axolotls believe safety is paramount. All team members were required to attend safety training for equipment used for the project including power tools, soldering irons, and chemical substances.

Fig. 11. Frame team abiding by mandatory hand safety apparel when handling heat tools

Fig. 12. Electronics team member soldering on static resistant surface with proper soldering iron and holder.

Safety: Tether

The Axolotls took precaution to keep all wires and tubing in a tether. Tether strain relief is located near the back longitudinal thruster (Fig. 13).

Fig. 13. Construction of the tether. Length: 15.24 m. Contents: pneumatic tubing, thruster connectors, and camera connections.

Safety: Cameras

The connections to the cameras were sealed and waterproofed in epoxy. This allows the cameras to be placed in an adjustable mount and ensured no water contacts the electronics.

Safety: Shroud

The Ambitious Axolotls chose to model and 3D print the thruster shrouds. When designing the shrouds, the Axolotls tried to maximize hydraulic flow while minimizing the potential for the propeller to make contact with external objects. This includes but is not limited to body parts, marine flora, marine wildlife, solid sea pollution, and other marine tools and equipment.

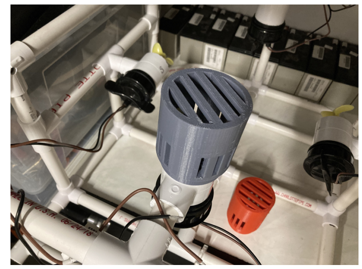


Fig. 14. Second design of *Buggy's* shrouds.

The first shroud was made from a 3d print found on the internet in order to understand what is need to protect the motor blades. The printed shroud fit on the thruster but did not allow enough water flow for efficient propulsion. With this in mind, the team designed a second shroud using Fusion 360 (Fig 14). Multiple slots were created using the CAD software to let water flow in and out of the shroud as the motor produced thrust, but were small enough to not let body parts or other objects through.

Fig. 15. Left: Final design of the thruster shroud. Right: Final shroud design with mesh on the top and sides of the shrouds.

However, when testing the ROV in the pool it was found that the shroud does not allow sufficient water flow, which limited thrust and maneuvering. So another iteration of the shroud was made to allow more flow through the shroud (Fig. 15; left). In addition, the base of the shroud has a semi-circle removed from it so that it can slide over more of the PVC mount. Finally, metal mesh and a laser cut acrylic mesh were adhered with hot glue to the in-flow and out-flow openings of the shroud for safety (Fig. 15; right).

Testing

The Ambitious Axolotls achieved many goals through the design, construction and operation of the ROV. Achievements were obtained by sticking to engineering design principles: research, build, experiment, and rework. As a first time competitor, the team conducted prior research for each aspect of the ROV design to understand the most efficient way to begin the project. The members built multiple prototypes for each part of *Buggy,* and each member expressed their thoughts and creative feedback to help improve the design (Fig. 16). From there, the parts underwent testing to assess how capable the design was at achieving key objectives and to catch any overlooked criteria needed for the part. Lastly, if the part need for the vehicle was not working as intended and/or there was a more functional design, then the team member(s) would discuss and redesign that part (Fig. 16). From there the new part would go through all the stages again.

Fig. 16. Members of the team consulting about the ROV build, the control box, and manipulator.

Testing: Troubleshooting

Though the team completed many achievements, there were also a number of challenges that the team had to overcome. During the first water test, the Axolotls were about to test *Buggy's* maneuverability in the water and finish installing the tether to the motors. Before soldering the wires and putting it in the water, two of the members were testing if the motors were rotating in the correct direction. However, the control box used for testing shorted a major component. The members suspected that the ground wire and some of the wires leading to that component were the problem since the ground was not soldered on correctly and the pins that held the other wires were loosened. To resolve the issue, the team replaced the part and did a thorough inspection of the control box.

A second challenge occurred on the last build day for the team. The team had to finish installing the last wires through the tether and install a strain relief where the tether connects to the ROV. The team had put wires through the tether sheath in order to test motors and cameras. However, now the tubing and wires for the claw actuator needed to go through the tether. Unfortunately, the lengths of the wires and tubes were not equal. So, the Axolotls took all the components out of the tether, grouped them together, making sure that the lengths are equal, and fed them back through the tether. This required significant effort and time and the team learned a valuable lesson about tether design and construction.

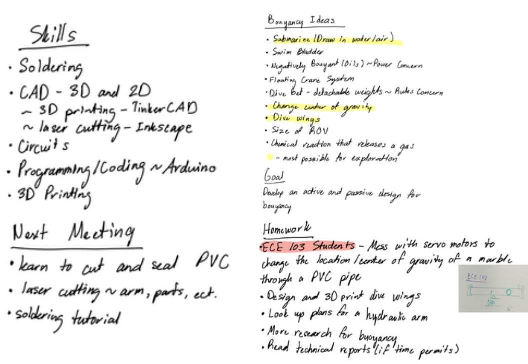
After overcoming unexpected hardships, the Ambitious Axolotls developed protocols and criteria for checking the quality of solders, the security of control box components, and ensuring no wire contact. The team also learned the importance of early tether management and accounting for how many wires and tubing need to go through.

Logistics

The Ambitious Axolotls kept in contact both in person and online using the Discord app. An online server was set up to create easy accessibility to documents for team members and allow project management staff to remind the group of deadlines. All deadlines were mentioned at the start of every in-person meeting. Notes were posted after the conclusion of each in person meeting (Fig. 17).

The first month of meetings were dedicated to whiteboard brainstorming sessions and appointing heads of teams. From there, construction started.

Request for parts to purchase required the name of the part, a link to purchase, and reason for request. All expenses were logged in a spreadsheet (Fig.18).



Skills
- Soldering
- CAD - 3D and 2D
  ~ 3D printing - TinkerCAD
  ~ laser cutting - Inkscape
- Circuits
- Programming/Coding ~ Arduino
- 3D Printing

Next Meeting
- learn to cut and seal PVC
- laser cutting ~ arm, parts, ect.
- soldering tutorial

Bouyancy Ideas
- Submarine (Draw in water/air)
- Swim Bladder
- Negatively Bouyant (Oils) ~ Power Concern
- Floating Crane System
- Dive Bet - detachable weights ~ Rules Concern
- Change center of gravity
- Dive wings
- Size of ROV
- Chemical reaction that releases a gas
- most possible for exploration

Goal
Develop an active and passive design for bouyancy

Homework
- ECE 103 Students - Mess with servo motors to change the location/center of gravity of a marble through a PVC pipe
- Design and 3D print dive wings
- Look up plans for a hydraulic arm
- More research for buoyancy
- Read technical reports (if time permits)

Fig. 17. Examples of posted meeting notes created during the brainstorming phase

Item #	Vendor	Product Description	Cost ($)	Quantity	Extended ($)		Comments
1	Amazon	High Tech Servo Motors (2 Pack)	31.49	1			
2	Amazon	25kg High Torque RC Servo Waterproof	17.99	1			
3	Amazon	120 pcs Breadboard Jumper 20cm Wire Length	6.99	1			
4	Ebay	Bluetooth 4.0 CC2540 Serial Wireless Arduino Android/IOS	5.49	1			
6	Amazon	Ultra Low Impedance Heatsink Compound	7.99	1			Stand Alone Thermal paste
7	Amazon	Pnuematic Cylinder Actuator	17.99	1			75mm Bore Double Action with Y connector
8	Amazon	Pnuematic Tube Fittings	5.49	1			Pack of 2
9	Amazon	Hose Tubing	11.99	2	23.98		12 (meter) Polyurethane Tube Fittins
10	Amazon	Hose Fitting for Tubing	5.49	1			1/4" tube OD x 1/4" NPT Push to connect fitings
11	Amazon	Hose Fitting for Compressor	5.49	1			1/4" Air Compressor Connector Female Thread
12	Amazon	Valve Control	18.99	1			1/4" NPT 3 Position 4 way
13	Amazon	1/4" Exhaust Muffler Filters	13.99	1			10 Pcs Air Pnuematic Flow Controller

Fig. 18. Example of the spreadsheet used for purchasing and tracking the budget

Acknowledgements

The Ambitious Axolotls would like to acknowledge and thank their constituents from the engineering department of Estrella Mountain Community College Dr. David Benson. Steven Shapiro, manager of EMCC's MakerSpace, for allowing the team to use the space for construction, and storage, and giving advice when asked. They would also like to thank Ray Surdilla from Life Sciences and Liahla Roberts for assisting with budgeting and ordering parts. Also, NSF for sponsoring the team. As well as, the MATE ROV Competition for the invitation to compete.