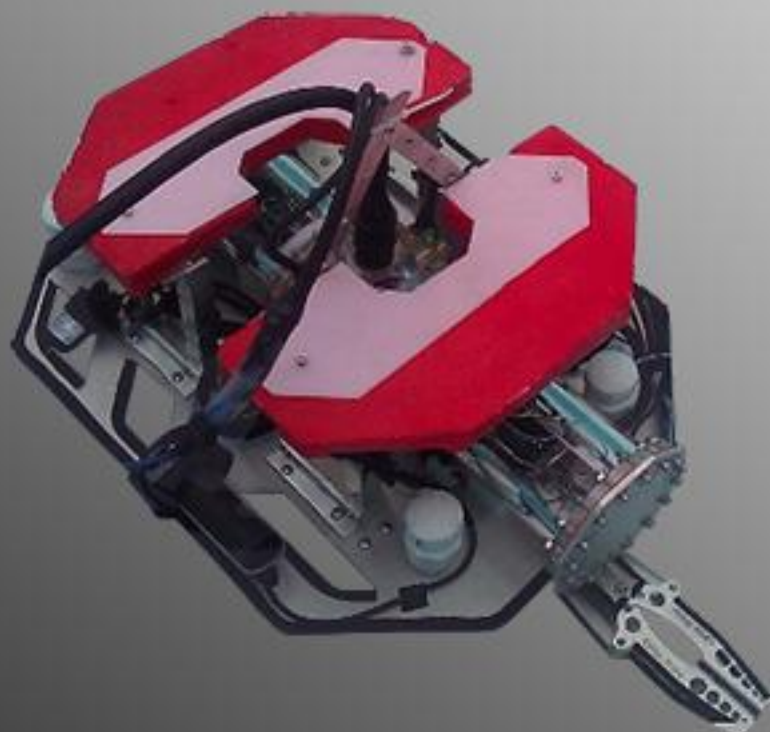
Robotic Aquovations

Ohio State University, Columbus, Ohio

TECHNICAL REPORT

2013 MATE International Competition EXPLORER Class



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UNDERWATER ROBOTICS

AT THE OHIO STATE UNIVERSITY™

ABSTRACT

This technical report is meant to provide information pertaining to the underwater remotely operated vehicle, Block-O-Bot, designed specifically for the 2013 Marine Advanced Technology Education (MATE) Center International Competition. Block-O-Bot was designed, constructed and tested by Robotic Aquovations in Columbus, Ohio. To create a reliable remotely operated vehicle (ROV) for the client, MATE. Robotic Aquovations utilized the top engineers at the company to create a completely unique ROV that caters toward all of the client's requirements.

Block-O-Bot was designed to maintain functionality of the Regional Scale Nodes (RSN) cabled observatory located off the coast of Washington and Oregon. Specific tasks the ROV can perform include installing the Scientific Interface Assembly (SIA) into the Backbone Interface Assembly (BIA) of a primary node, connecting the Cable Termination Assembly (CTA) into the BIA, installing the secondary node and providing power and communications by connecting to the SIA, installing a transmissometer created for optimal functionality by Robotic Aquovations, removing and replacing an Acoustic Doppler Current Profiler (ADCP) from a water column mooring, and ridding the site of dangerous biofouling.

The ROV has been equipped with four 19V DC thrusters, a multipurpose, actuating arm, numerous cameras, a watertight, cylindrical electronics housing, ballast trim modules, and a waterjet-cut aluminum frame. The control system is comprised of an Arduino Mega 2560, a laptop computer, and a joystick. An Arduino was programmed with the Arduino language in order to communicate with a computer. Block-O-Bot ROV emphasizes simplicity and multipurpose use.

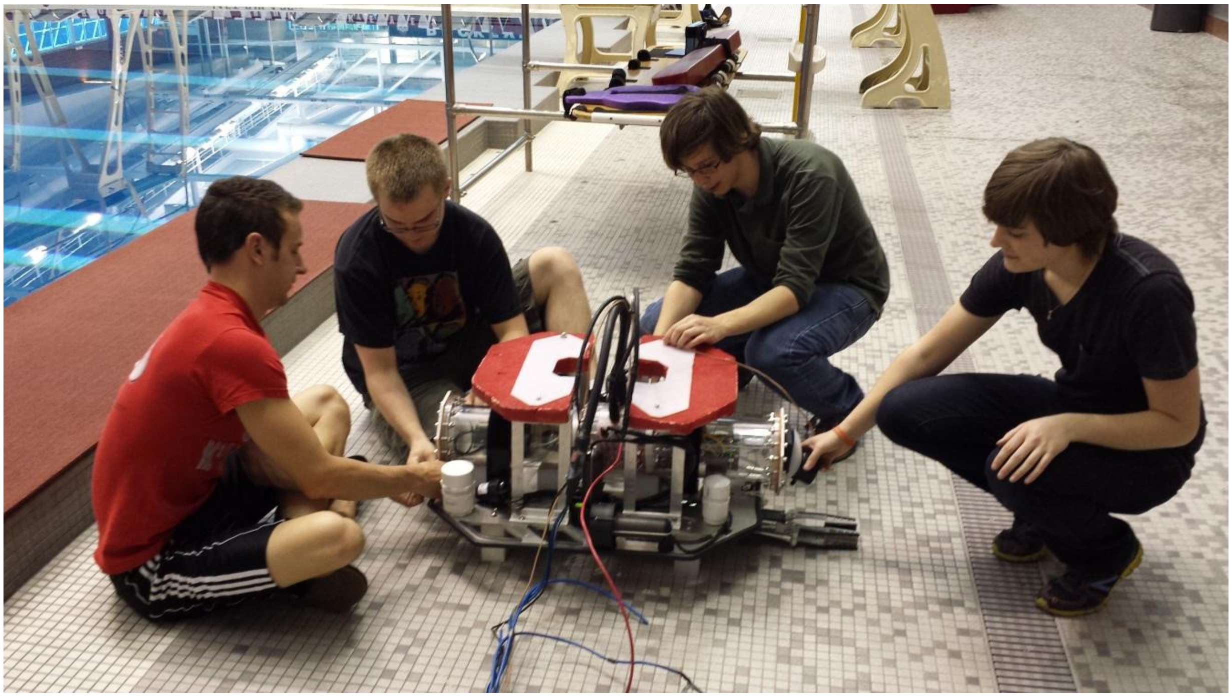

Figure 1: Photo of team members working on ROV

TABLE OF CONTENTS

Abstract **1**

1. Budget **3**

2. Design Rationale **6**

2.1 Electronics Housing **6**

2.2 Mounting Frame **7**

2.3 Propulsion **7**

2.4 Ballast Trim Modules **8**

2.5 Claw - Gripping Mechanism **8**

2.6 Measuring Device **8**

2.7 Turbidity Sensor **8**

2.8 Cameras **9**

3. Electronics and Control **9**

3.1 Surface Control System **9**

3.2 Program Flow Chart **10**

3.3 Tether **11**

3.4 Power Conversion **11**

3.5 Motor and Tool Package Control **11**

3.6 Electrical Schematic **12**

4. Challenges **13**

5. Safety **14**

6. Troubleshooting Techniques **14**

7. Learning Experience **15**

8. Future Improvements **15**

9. Reflection **16**

10. References **17**

11. Acknowledgements **17**

Appendix A – Code .... **i**

1. Budget

The following tables illustratate the overall budget and bill of materials for fabrication of Block-O-Bot and travel associated with the 2013 MATE International ROV Competition.

Table 1: Budget for 2012-2013 Underwater Robotics Team

Complete 2012 - 2013 Budget	
Savings and Income	
Saved and Incoming Funds (see sources of funding for details)	$16,808.00
Materials	
Expense Item	**Cost**
ROV Materials and Fabrication (see itemized bill of materials for details)	($6897.06)
Reserve Funds	
Expense Item	**Cost**
2013 Reserve Funds	($1,000.00)
Travel and Shipping	
Expense Item	**Cost**
Roundtrip Airfare	($4,512.00)
Tacoma Hotel Rooms	($1,380.40)
Transportation To/From Airport	($250.00)
Shipping Costs (ROV and Supplies roundtrip)	($600.00)
Total Costs	$14,639.46
Budget Difference	**$2,168.54**

Table 2: Sources of Funding

Source	Amount
Funds saved from 2011-2012	1,956.00
Bonus funding earned through the College of Engineering	1,042.00
Individual outside gifts	450.00
Engineers' Council	3,000.00
College of Engineering Matching funds	2,960.00
Team Member Contributions	2,400.00
Battelle Grant	5,000.00
Total	**16,808.00**

Table 3: Itemized Bill of Materials

Qty.	Item	Unit Cost	Total Cost Per Item
	Wire Connectors		
1	10-pin connector Inline (MCIL10M)	$59.50	$59.50
1	10-pin connector Bulk Head (MCBH10F)	$89.60	$89.60
1	3-pin connector Inline (MCIL3M)	$23.66	$23.66
1	3-pin connector Bulk Head (MCBH3F)	$45.89	$45.89
1	12-pin connector Inline (MCIL12M)	$66.50	$66.50
1	12-pin connector Bulk Head (MCBH12F)	$103.39	$103.39
4	4-pin connectors Inline (MCIL4M)	$28.98	$115.92
4	4-pin connectors Bulk Head (MCBH4F)	$52.85	$211.40
1	High Power 4-contact Inline (HPIL4M,)	$106.54	$106.54
1	High Power 4-contact Bulk Head (HPBH4F)	$169.20	$169.20
1	Subconn Connector Freight	$25.00	$25.00
1	Dow Corning Molykote 44 Grease, 5.3 oz tube (suggested grease for connectors)	$26.95	$26.95
1	Loctite 222 10 mL bottle	$12.75	$12.75
2	Ultra-Clear Tygon PVC Tubing 3/4" ID, 1" OD (1 foot length)	$6.10	$12.20
2	Underwater Silicone Sealant (2.8 oz tube)	$6.06	$12.12
	Propulsion & Control		
4	Seabotix BTD 150 ROV Thrusters	$695.00	$2,808.25
1	SeaMATE Controller Board	$340.00	$340.00
1	Arduino Mega 2560	$64.99	$64.99
3	Sabertooth 2x12 Motor Controller	$79.99	$239.97
2	Zahn DC/DC Converter (48V to 24V)	$99.00	$198.00
1	Murata DC/DC Converter (48V to 12V)	$44.74	$44.74
	Frame		
1	36" x 24" Al-6061 sheet, 0.25" thick	$130.00	$130.00
1	2.5"x4"x12" UHMW Polyethylene	$52.86	$52.86
1	8ft 1"x1", .25" thick, Al 6061 T6 90 deg Angle	$13.49	$13.49
1	4ft 1"x1" Al 6061 T6 90 deg Angle	$7.71	$7.71
2	.125" thick, 12"x12" Virgin Plastic NATURAL Sheet UHMW	$4.40	$8.80
2	2"x2" Easy-to-Machine Chemical-Resistant Polypropylene (1 foot)	$11.02	
	Arm Assembly		
1	6"x24" 304 SS McMaster #9085K41 (arm support)	$32.29	$32.29
1	1 1/4" Thick, 2.5"x12" White Delrin	$27.75	$27.75
1	.5"x4"x12" Easy-to-Machine Impact-Resistant ABS	$8.78	$8.78
1	1"x2"x12" white delrin	$19.03	$19.03
1	2"x2"x12" white delrin	$33.54	$33.54
1	.25"x20 , 8" length (10/pack) Al-6061	$12.25	$12.25
1	18-8 SS .25-20 Hex Nut (100/box)	$4.57	$4.57

1	Nylon Unthreaded Round Spacer 1/2" OD, 11/16" Length, 1/4" Screw Size	$9.70	$9.70
1	1/4"-20, 1/2 long, SS Socket Head Cap (50 per box)	$6.68	$6.68
1	Worm and Worm Gear (Boston Gears)	$56.00	$56.00
1	18-8 Stainless Steel Socket Head Cap Screw, 1/4"-20 Thread, 4" Length, packs of 10	$7.37	$7.37
1	High-Strength Aluminum (Alloy 2024), Tight Tolerance, 3/16" Diameter, 1' Length	$4.14	$4.14
1	Alloy Steel .001" Oversized Dowel Pin, 1/16" Diameter, 3/4" Length, packs of 25	$8.37	$8.37
1	Corrosion Resistant Dowel Pin, Type 316 Stainless Steel, 3/32" Diameter, 3/4" Length	$7.68	$7.68
1	Brass Standard Key Stock, 1/8" X 1/8", 12" Length	$1.78	$1.78
1	Fully Keyed Aluminum Drive Shaft, 1/2" OD, 1/8" Keyway Width, 6" Length	$12.69	$12.69
1	White Delrin (R) Acetal Resin Rectangular Bar, 1-1/2" Thick X 3" Width, 1' Length	$37.20	$37.20
	Electronic Materials		
1	Black PVC Heat-Shrink Tubing	$19.66	$19.66
	Electronics Housing		
2	Super-Grip Black Nylon Cinching Straps 2" wide 36" long	$11.63	$23.26
2	Aluminum 6061-T651 PLate .25" thick, 8"X8"	$9.18	$18.36
1	Aluminum 6061-T6 PLate .125" thick, 12"X12"	$14.53	$14.53
1	Impact-Resistant Slippery UHMW Polyethylene 5" Rod 1 foot long	$44.10	$44.10
	Cameras		
2	!nventivity Color Cameras	$29.50	$59.00
	Light Opacity Module		
1	Electrical components (CDS Cell, resistors)	$5.00	$5.00
1	2-13/16" Width, 1-5/8" High, Brown, Push-to-Open Grab Latch	$6.90	$6.90
	Mission Props		
1	PVC pipe materials	$140.00	$140.00
1	Various small items (hinges, nuts, bolts, rope)	$30.00	$30.00
	Team Apparel		
1	Competition team polo shirts	$300.00	$300.00
	Administration		
1	Reimbursement	$380.00	$380.00
1	Team Registration	$100.00	$100.00
36	Pool Time	$13.25	$477.00
		Total Cost:	**$6,897.06**

2. Design Rationale

Block-O-Bot was designed to efficiently incorporate all required tool packages and remain flexible for possible modifications if needed. The final design resulted from integrating the following systems: electronics housing, mounting frame, ballast trim modules, and a multipurpose gripping mechanism. During the design phase, focus was placed on watertight sealing, versatile tool packages, optimal camera placement and buoyancy. All of the ROV components were modeled using the computer aided design (CAD) software package SolidWorks™ 2012 to ensure compatibility among all designed parts.

2.1 Electronics Housing

The housing is a cylindrical, watertight container composed of mostly acrylic (see **Figure 2**). The main segments are end caps, sealing collars, electronic control compartment, central connection hub, and power conversion compartment.

The end caps are located at either side of the housing and are used for internal electrical component repair and modifications. They are bolted to the ends of the housing with a rubber gasket between the cap and the sealing collar for a watertight seal.

The sealing collars were created to achieve maximum gasket surface area. The collars were chemically bonded to the electronic control compartment and power conversion compartment by applying a solvent to the acrylic.

The electrical control compartment contains the Arduino Mega 2560 microcontroller and three Sabertooth motor controllers. These components are mounted on an aluminum plate that is constrained with two cylindrical end pieces made of Delrin®.

The central connection hub provides a large area for mounting seven SubConn® watertight bulkhead connectors. These connectors are used for inputting power, communicating to the surface, motor control, and camera signal and power. The acrylic was threaded and a flat surface was machined for each connector to ensure a leak-proof seal. The central position of the hub allows for easy wire access to both sides of the housing.

The power conversion compartment is similar to the electronic control compartment except that it contains two Zahn 48V to 24V and one 48V to 12V DC/DC converters.

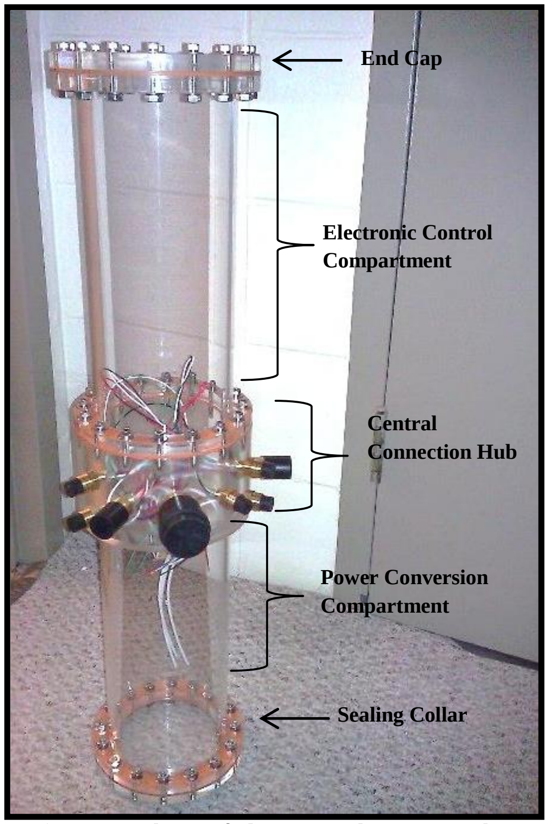

Figure 2: Photo of electronics housing with labels.

2.2 Mounting Frame

The mounting frame was designed to provide secure positions for each subsystem (propulsion, buoyancy, tool packages, and control). The frame consists of the base plate, electronics housing mounts, and the buoyancy structure (**see Figure 3**).

Figure 3: Waterjet base plate

The base plate was constructed with a 6061-aluminum alloy sheet. The aluminum sheet was cut using a waterjet which provided a finished product to the exact specifications of the design. Several gaps were created in the base plate to supply adequate water flow around the ROV and propulsion system. Mounting holes for low tolerance subsystems were cut using the waterjet to guarantee correct placement. To prevent damage to the robot, four supports were mounted to the bottom of the base plate and rubber edging was placed on the aluminum perimeter.

The electronics housing mounts act as cradles for the cylindrical structure and preserve the orientation of the housing. Rubber pads were glued to the surface that is in contact with the electronics housing to prevent slippage or rotation. To secure the housing to the base plate, Velcro straps fasten to the base, pressing the cylindrical housing onto the mounts (see **Figure 4**).

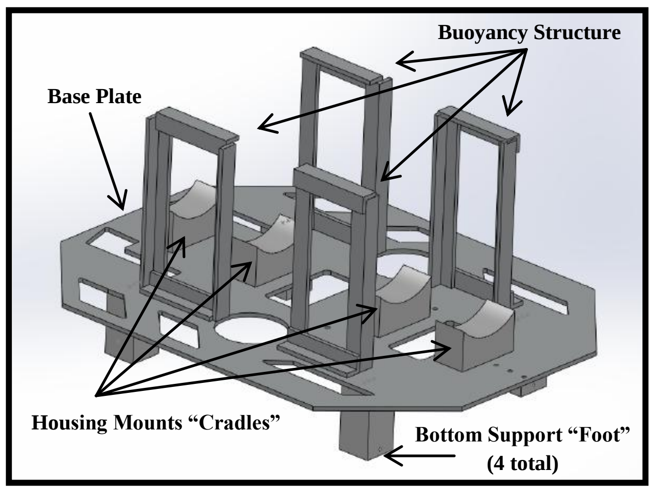

Figure 4: Solidworks™ model of mounting frame

The buoyancy structure was designed to secure two pieces of high density foam to the top of the ROV. The foam forms the shape of an Ohio State Block O and is used to maintain neutral buoyancy while underwater. The structure consists of four rectangular assemblies, placed on the right and left sides of the electronics housing. The structure was assembled with 90 degree angle aluminum extrusions and stainless steel nuts and bolts.

2.3 Propulsion

The ROV is driven by four 19V Seabotix BTD150 thrusters (see **Figure 5**). The configuration of the thrusters allows for vertical motion (Z-axis) and unrestricted motion in the horizontal plane (X-Y-plane). The speed of the motors is controlled by utilizing pulse width modulation to vary the voltage that is supplied to the thruster. When running at 19V each thruster draws a maximum continuous amperage

Figure 5: Photo of Seabotix thruster (Image from Seabotix.com)

of 4.25 A and provides a continual bollard thrust of 2.2 kgf.

2.4 Ballast Trim Modules

Figure 6: Ballast trim modules

The ballast trim modules (see **Figure 6)** allow for fine balance control to calibrate the center of gravity and to account for varying buoyancy changes across multiple water environments. Adding small weights to the trim modules is more effective than modifying the amount or placement of the high density foam. The volume of high density foam attached to the top of the ROV was designed to be slightly high to account for the use of the ballast trim modules. Each module is composed of a PVC cap, plug, and coupling. The combination of these items produces a closed cylindrical compartment capable of storing a certain volume of weight.

2.5 Claw- Gripping Mechanism

The arm and claw was designed as an adaptable multipurpose tool (see **Figure 7)**. An axle and gear assembly at the rear of the claw drives the arm vertically for fine tune adjustments. The claw and arm is constructed of mostly stainless steel sheet metal, Delrin®, and ultra-high-molecular-weight polyethylene. The stainless steel components were laser cut and the plastic pieces were machined with a mill, band saw, and lathe. The claw is opened and closed with a threaded rod powered by a 12V Johnson bilge pump cartridge. A threaded slider is driven back and forth across the rod and forces two linkages to open and close the claw. The vertical actuation is powered by another 12V Johnson bilge pump which rotates a worm gear system. The arm and claw is mounted beneath the base plate, protruding past the front perimeter. The claw is utilized to complete the following tasks: Installing SIA into BIA, inserting CTA into the bulkhead connector on the BIA, releasing the secondary node via pin, removing secondary node from elevator, installing secondary node in designated location, leveling out secondary node, opening door of BIA, installing secondary node cable connector into SIA, installing turbidity sensor, disconnecting power to mooring platform, unlocking hatch, opening hatch, removing ADCP from the mooring platform, installing replacement ADCP, closing hatch, re-locking hatch, reconnecting power to mooring platform, and removing biofouling. Block-O-Bot's claw and arm is a genuine multipurpose tool.

Figure 7: Photo of horizontal claw

2.6 Measuring Device

To accurately measure the distance from the BIA to the designated location for secondary node placement, a retractable tape measure was modified with a large hook on the end to attach to the BIA. To view the measurement a camera was placed above the device. The text on the tape measure was also enlarged for easy viewing by the camera.

2.7 Turbidity Sensor

The turbidity sensor consists of a 28,500 mcd white LED, and a cadmium sulfide photo resistor. The photo resistor is connected from ground to an analog pin on an Arduino UNO located on the surface. The UNO has firmware identical to the Arduino Mega located in Block-O-Bot via the software Processing. Processing graphs the values returned on the screen.

2.8 Cameras

For clear viewing of underwater surroundings, the ROV was equipped with three Anaconda x10 (see **Figure 8)** color cameras and two !nventivity™ color cameras. The Anaconda x10 cameras were sealed with epoxy in a clear plastic container to ensure a watertight seal. The !nventivity™ cameras were purchased as watertight cameras and did not require any modification. To see the mission site, the cameras were placed in the following positions: two facing the front to give depth perception, one looking below the ROV to view the claw when it is rotated downwards, one to observe the measured distance for the secondary node placement, and one to monitor any tether entanglement.

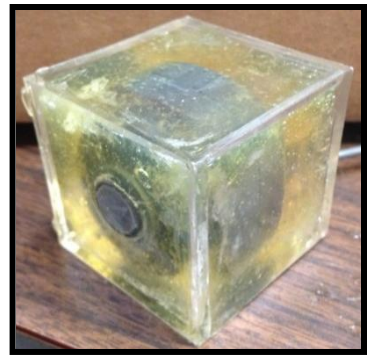

Figure 8: Sealed Anaconda x10 camera

3. Electronics and Control

There are four main elements to the electronics and control system, which include the surface control system, tether, power conversion and motor and tool package control.

3.1 Surface Control System

Block-O-Bot is controlled by an Arduino Mega 2560 which receives user data from a surface computer equipped with Processing. Processing, a program designed to facilitate graphical interface, was used to receive input from a joystick. This was accomplished using user defined classes within the proControl library. These libraries simplify the joystick input and let a single command read the value from any button or slider. The output pins on the Arduino are directly command by Processing to control the Sabertooth motor controllers.

A Logitech Attack 3 joystick outputs x- and y-coordinates for motor speed and direction. A dial located on the joystick is used for z-axis input. Multiple button inputs can be configured for a variety of tasks. The program receives the x, y, and z values from the joystick ranging from -1 to 1. A cubic equation is then used to increase the sensitivity around the origin. To achieve proper motor control in the x-y plane, the joystick coordinate is rotated 45˚ clockwise and scaled accordingly. These values are thenwritten to the Arduino PWM pins to control the motor controllers.

The communication between Processing and the Arduino is achieved through serial USB connection. A modified MIDI protocol is used, called SysEx, which allows for longer command streams than the normal 2 bytes for MIDI. Firmware was uploaded to the Arduino which allows for Processing to directly control it using similar digitalWrite() and digitalRead(), analogWrite() and analogRead() commands.

3.2 Program Flow Chart

The control program logic is shown in **Figure 9**.

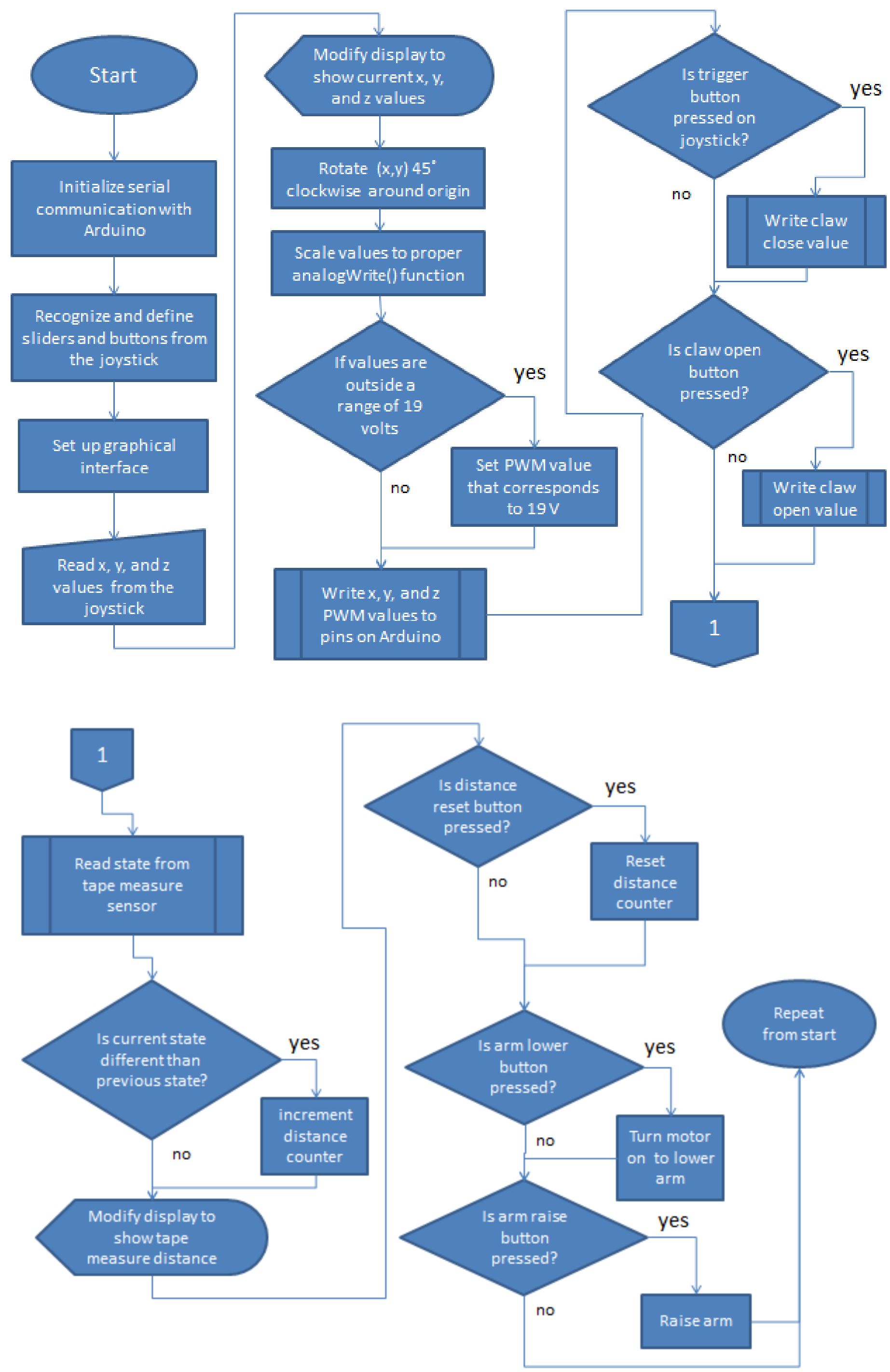

Figure 9: Program flow chart

3.3 Tether

The tether supplies Block-O-Bot with power and offers communication and camera video signal between the ROV and the surface control system. Power is sent to the ROV with two speaker cables, and communication and camera video signal are accomplished with two cat 5e cables. Communication between the surface control system and the ROV requires USB extenders for data communication through the 30 meter CAT 5e.

3.4 Power Conversion

The provided 48V is converted to voltages of 24V and 12V to power thrusters, tool packages, Arduino microcontroller, and cameras. To convert from 48V to 24V, two Zahn DC/DC converters (see **Figure 10**) were used which could each supply a maximum amperage of 15 A. The horizontal thrusters and are powered by the first Zahn converter and the vertical motors and claw are powered by the second converter. A 48V to 12V Murata DC/DC converter supplies power to the Arduino microcontroller and the cameras.

Figure 10: Photo of Zahn DC/DC converter (http://www.zahninc.com/sd1xspec4824280.html)

3.5 Motor and Tool Package Control

The thrusters and tool packages are controlled through the surface control system by a joystick. The Arduino microcontroller receives PWM output values from the program and sends these signals to the Sabertooth motor controllers. The Sabertooth motor controllers drive the Seabotix thrusters and claw assembly. The Sabertooth motor controller has several modes which make them a flexible component that could be used for other purposes in the future. The analog mode was utilized for its simple input signal requirements. In analog mode, the Sabertooth motor controllers convert the input signal to an output voltage for each motor based on a signal range of 0V to 5V, where 0V indicates full negative power, 2.5V indicates power off, and 5V indicates full positive power. This is an easy signal to acquire from the joystick output values. Once the Arduino microcontroller receives the PWM signal from the surface control system, the signal is reproduced through a digital output pin. In order to transform the PWM signal into an analog signal, an RC filter was used (see **Figure 11**). The filter smoothes out the digital PWM signal into the desired analog signal.

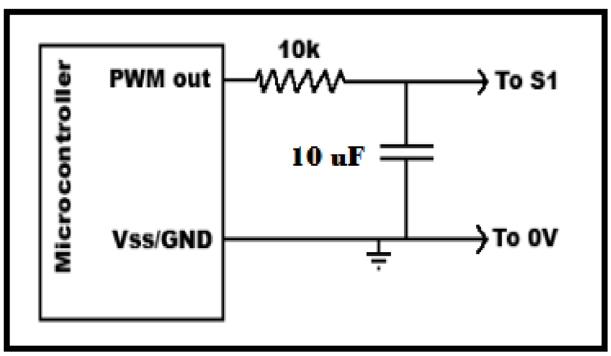

Figure 11: Diagram of PWM to analog filter

3.6 Electrical Schematic

The electrical schematic is shown in **Figure 12**.

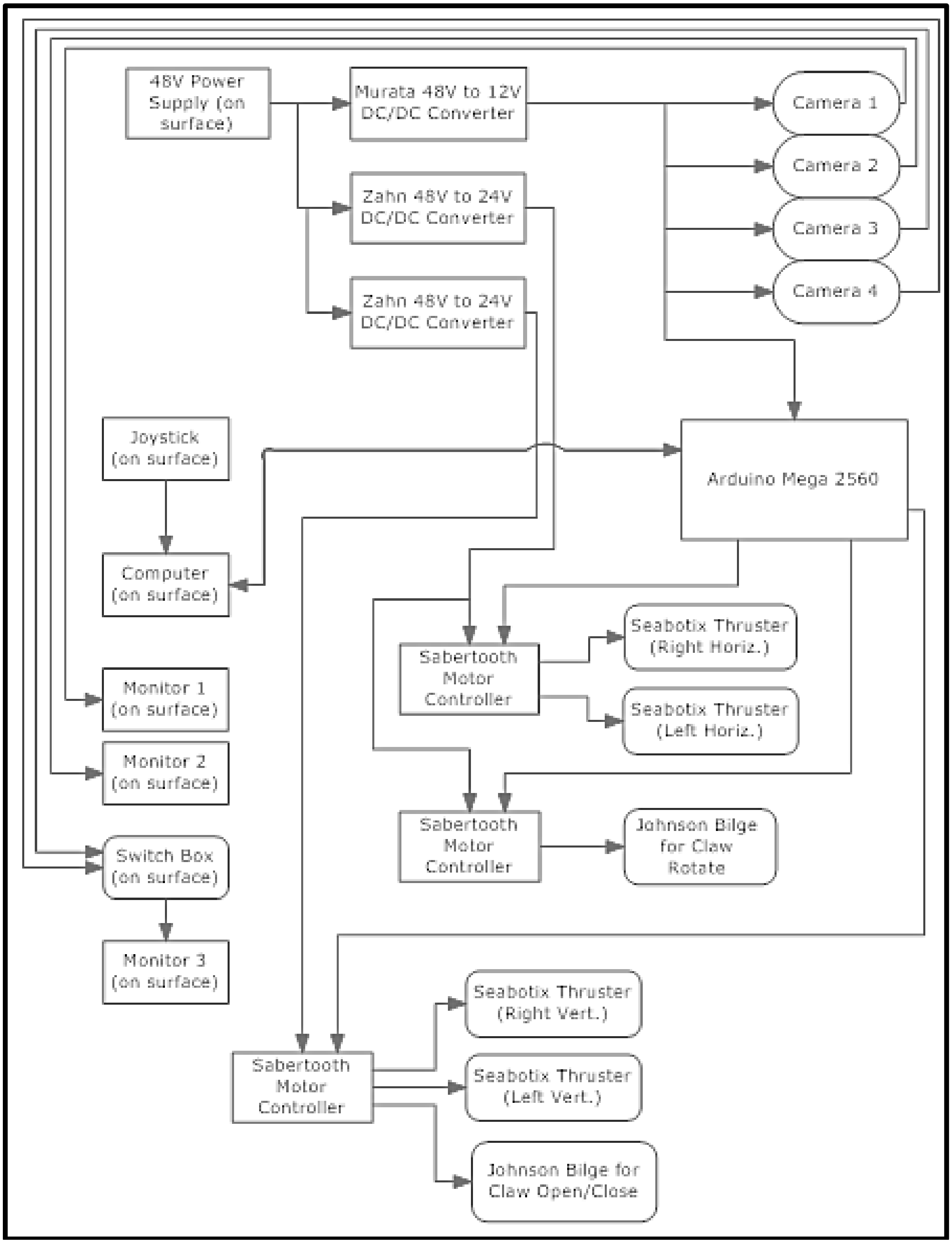

Figure 12: Electrical Schematic

4. Challenges

The ROV team at Ohio State and Robotic Aquovations is still a young, up and coming student group that might seem slightly misplaced at a school whose engineering project teams are dominated by well-established motorsport projects. The team has been in existence for less than three years and in that time the company's two foremost challenges have been to build a sustainable budget and expand team knowledge of ROV design. The team's ROV designs in each of the past three years have been a reflection of its growth in both those areas. Each work day has been a learning experience that has only bettered the team.

Specifically, waterproofing has and will remain a challenge, but the Block-O-Bot's watertight electronics housing is a major redesign from last year that has proven to be a wonderful success. The previous year's housing was unique in that it was a low profile, lightweight, carbon fiber design that, unfortunately, leaked like a sieve despite its “cool” factor. The housing was formed by a mold that disallowed the necessary surface flatness required to press against custom seal block o-rings for wire passage. The team realized the housing's fundamental engineering flaw and created the current cylinder design. The redesign has proven to be a great success in protecting its critical electronic cargo.

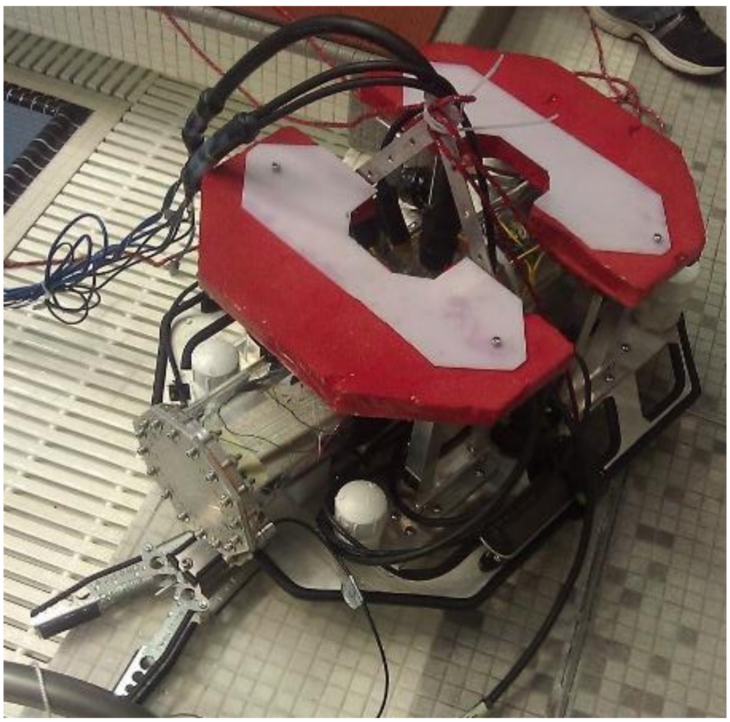

Figure 13: Intact photo of ROV

Electronic control system design has proven to be another challenge for the team because of its many mechanically minded individuals. The team has been working to recruit electrical and computer science engineering members, but in the meantime, the group has been required to step outside its comfort zone to formulate an effective, albeit simple, electronic and control system. Several systems have been utilized, including the SeaMATE control board and a fair share of Arduino based control methods using both Playstation 3 controllers and a joystick. The team has seen connection time outs, communication losses, bad MOSFET transistors, and an exploding capacitor. Despite the team's electronic tribulations and need for more electronically skilled members, we continued to learn, adapt, and emphasize safety. Block-O-Bot's final control system has been reliable and a product of tremendous growth.

One challenge for a young, self-taught ROV team is to recognize and deal with haunting mistakes of its much less experienced past. These are mistakes that do not immediately reveal themselves, but that with time, can create real setbacks. Young mistakes from more than a year ago finally revealed their damage in the original, reused tether. A water leak was discovered in the communication line that most likely occurred at some point in the last year or before. The only sign of past cable leakage was wire corrosion discovered this May. Capillary effects carried the corrosion throughout lengthy sections of cable. A new tether with new wiring was required and the situation was once again a learning experience to pass down to future members. In all the team's challenges the most important thing was to learn and adapt. Mistakes occur when a team is learning the ropes and building its skills. At the same time, underwater ROVs present a unique set of inherent challenges. It is the duty for current team members to pass down their lessons learned and to continue growth in the team's overall skills, knowledge, and experience.

5. Safety

An important aspect of any engineering project is safety. To make the Block-O-Bot as safe as possible several techniques and procedures were implemented. Due to the risks associated with throwing an electronic filled capsule into a five meter deep pool, the selection of components was essential. The Sabertooth motor controllers used have over-current and thermal protection, along with large heat sinks attached to either side. In case of a motor stall, the controllers would be left unharmed, and potential component damage would be averted. Heating of the components in general was also a safety concern. The components are designed to function within a certain temperature range, and if they are subjected to extreme heat, they could release smoke or cause a loss of control of the motors. To combat this, proper heat sinking was employed by mounting components to aluminum plates to facilitate heat conduction. A fan circulates air through the housing, and extensive testing was completed to conclude that heat was managed within required limits.

A 20 amp circuit breaker is used to quickly turn on and off power and to ensure that current levels remain low. Inline fuses are used within the electronics housing to protect cameras and limit current draw from potentially hazardous power converters. Since communication loss is a possibility, the control program was modified to shut off power to thrusters while there is no user input. If communication was lost, Block-O-Bot would not damage itself, nearby divers, or other ROVs. Any live power situation required procedural "all clear", "power on", and "power off" call outs.

Exterior safety mechanisms include simple alterations to the ROV structure to make the vehicle safe for handlers and divers. Rubber edging was placed around the perimeter of the ROV for safe handling and to prevent injury. The thrusters are shrouded, and caution labels are present to prevent accidental injury. Additional labeling warns against any hazardous machine elements in the robotic arm.

6. Troubleshooting Techniques

In order to effectively troubleshoot problems, the company found it best to test individual components or variable in a systematic manner. One of the biggest problems encountered was that the control board would lose communication with the surface at seemingly random times. In order to solve this problem, steps were taken to first ensure that all wiring on the ROV was correctly implemented and that the program had no obvious flaws. After no issues were found, the tether was examined and it was discovered that the control board would lose communication at varying tether positions. Further examination showed physical wear to the communication cabling and new communication wire was installed. Further tests showed continued communication issues at times, and by eliminating most other possible problems, it was concluded that the communication issues were also caused, in part, by electromagnetic interference (EMI). The tether was remade to reduce the effects of EMI and successfully solve the communication issues.

The team has been able to troubleshoot and solve arising problems by systematically testing any possible cause of error. Although this process can be time consuming, it has proven to be the most effective way to narrow down the source of any problem.

7. Learning Experience

The experience of building Block-O-Bot taught the team many important skills, the most important of which were teamwork and time management. Many in the group had never worked with engineers outside of their discipline. This project taught those members critical, real world skills needed to combine electrical and mechanical engineering training into the creation of a professional end product. Team members learned how to better communicate across varying technical levels to collaborate and achieve design goals. Knowledge of time management skills were also imparted to the team particularly concerning a build schedule. The team has learned how to better project time requirements for post-production testing, control system creation, and debugging. Part of the engineering design process is to carefully plan required deadlines for each step of a long term project, and the team will certainly better utilize tools such as Gantt charts to improve future time budgeting. From tether damage, communication issues, and time budgeting, the team has learned many lessons the hard way, but sometimes learning the hard way has the greatest impact while striving for future improvement.

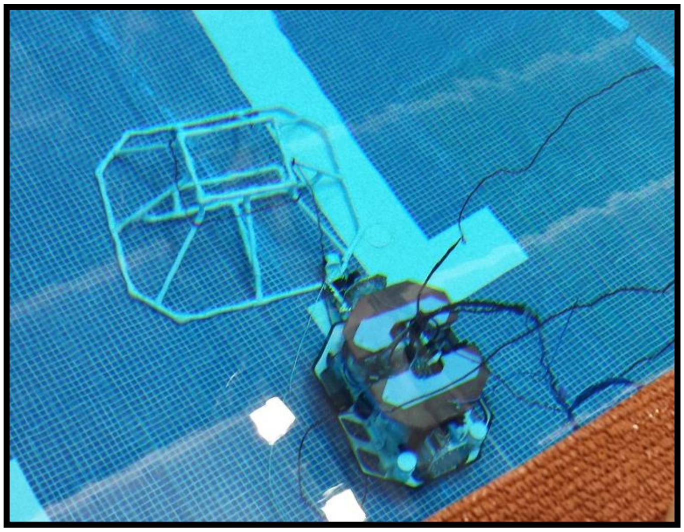

Figure 14: Photo of ROV during pool testing

8. Future Improvements

As a growing engineering project team it is our intention to continue our understanding of ROVs, electrical and mechanical design, and team working strategies. In the future we hope to increase the sophistication of the control system which will allow for increased safety features and implementation of temperature and pressure sensors.

Another vital matter concerns recruitment. This year’s team is quite small and those who are greatly involved include a narrow range of majors. To increase the knowledge base our team utilizes to design and build, it is our goal to reach out to the engineering majors such as computer science and electrical engineering.

An additional objective for the team is to educate our peers and prospective engineering students about the importance of underwater technology. By holding public events with the ROV, we can stimulate young minds and educate the community about what the oceans have to offer this world.

9. Reflection

"The devil is in the details," was the most used expression by my thermodynamics lecturer. And like many in the lecture hall, the material came easy and the expression seemed rather inapplicable. The same could be said about the other classes – unchallenging. Whether it was calculating pressures in a vapor-compression system or the entropy generation of a Carnot cycle, mistakes were inconsequential. Mistakes, by no means were encouraged, but their significance remained unrealized.

Reflecting on this competition year, the saying has never been truer. One of the more trivial aspects of the underwater remotely operated vehicle was the tether, or so we thought. As such we had braided the power and signal lines as a matter of convenience – causing a multitude of problems. With time, the friction between the wires stripped the insulation causing corrosion. Furthermore, given that the current draw through the power lines is highly irregular, electromagnetic interference can be of concern. Braiding of the wires would only worsen the extent of the electromagnetic interference causing our controls system to behave unstably. In hindsight, it seems silly to have spent so much time redoing code and debugging, given that the complication was in the tether.

When we learned that due to budgetary constraints we would be individually machining some of the parts, we quickly realized how unnecessary it was to have tight tolerances on every dimension. As such, we critically analyzed the design to eliminate excess features and implement new, simpler systems. Although, the parts would have functioned either way, we saved much time on the milling machines.

As important as it was to focus on the details of the vehicle, I believe that our greatest stride as a group was our collaboration abilities. Whenever someone had a midterm or other priorities, it always seemed that collectively we accounted for their share. In mid-April, our Block-O-Bot was a long ways from completion – the claw constantly jammed due the high friction between the threaded rod and the nut, the robot could not be controlled reliably, and the ROV had seen very little pool time. Somehow we were able to pull through. The end product is not a refined entity, yet I could not be prouder of what we have accomplished.

Looking back, I believe that the Ohio State coursework has given me a strong understanding to build upon; however, there exists a gap between the school work and engineering practices. Although this club was not mandatory to the engineering curriculum, I learnt a new vernacular – erudition in a unique perspective. The breadth of my undergraduate education is not engineering, rather engineering is the tool by which I apply what I have learned. And by participating in events like MATE, we can perfect our ability to engineer.

-Achal Singhal, 3rd year team member

10. References

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Moore, Steven W., Harry Bohm, and Vickie Jensen. *Underwater Robotics: Science, Design & Fabrication*. Monterey, CA: Marine Advanced Technology Education (MATE) Center, 2010. Print.

11. Acknowledgements

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- Nathan Vaughn, for his time and assistance with electronics and controls
- The Pittro and Roan families, for support and a monetary donation

Appendix A – Code

ROV Control Code

```
//set the target distance for task 1
float target_distance=__________;

//arduino motor ports and constants
 int LH=2;
 int V=3;
 int RH=4;
 int clawpin=6;
 int armpin=7
 int max_volts=229;
 int min_volts=26;
 float a=.3;


// sensor prots
int arm_sensor=1;
int tape_measure=5;

//libraries and classes for PS3 controller
import procontroll.*;
import java.io.*;

ControllIO controll;
ControllDevice device;
ControllSlider Y;
ControllSlider X;
ControllSlider Z;
ControllButton arm_up;
ControllButton arm_down;
ControllButton claw_open;
ControllButton claw_close;
ControllButton reset;

//libraries and classes for the Arduino firmata
import processing.serial.*;
import cc.arduino.*;

Arduino arduino;


PFont F;
int xvar=500;
```

```
void setup()
{
  size(400,400);
  background(255);
  F=createFont("arial",14, true);

  //for ps3 controller
  controll = ControllIO.getInstance(this);
  device = controll.getDevice(2);
  device.printSticks();
  device.printSliders();
  device.printButtons();
  device.setTolerance(0.05f);
  X= device.getSlider(2);
  Y= device.getSlider(1);
  Z= device.getSlider(0);
  Z.setTolerance(.2f);
  //left_trigger= device.getSlider(3);
  //right_trigger= device.getSlider(4);
  claw_open= device.getButton(1);
  claw_close= device.getButton(0);
  reset= device.getButton(number);
  arm_up= device.getButton(number);
  arm_down=device.getButton(nimber);

  //for initalizing the serial commiunication
  arduino = new Arduino(this, Arduino.list()[0], 57600);

  //sit pin mode for sensor input
  arduino.pinMode(arm_sensor, Arduino.INPUT);
  arduino.pinMode(tape_measure, Arduino.INPUT);

}

//initalize varialbles for sensor input
int limiter=0, timer=0, counter=0;
boolean time_start=false, current, previous=false;
float speed=0, estimated_distance=0, distance=0;




void draw()
{
  background(255);
  textFont(F,14);
```

```
  fill(0);

  //************get values from PS3 Controller*************
  float X_val=X.getValue();
  float Y_val=Y.getValue();
  float Z_val=0-Z.getValue();

  text("X-value:",20,40);
  text(X_val,75,40);
  text("Y-value:",20,60);
  text(Y_val,75,60);
  text("Z-value:",20,80);
  text(Z_val,75,80);

  Y_val=-1*Y_val;

  X_val=X_val*X_val*X_val*a+(1-a)*X_val;
  Y_val=Y_val*Y_val*Y_val*a+(1-a)*Y_val;
  Z_val=Z_val*Z_val*Z_val*a+(1-a)*Z_val;
  //X_val=128*X_val+128;
  //Y_val=128*Y_val+128;

  //rotate axis
float x_prime, y_prime;
x_prime = (X_val+Y_val)*.707;
y_prime = (Y_val-X_val)*.707;

  int right1, left1, right2, left2, rightout, leftout;

/*
   right1=int(255-Y_val);
  left1=int(255-Y_val);

  right2=int(255-X_val);
  left2=int(X_val);

  rightout=(right1+right2)/2+5;
  leftout=(left1+left2)/2+5;
  */
  //*********control right and left motors***********
  rightout=int(128*y_prime+132);
  leftout=int(128*x_prime+132);

  //prevents glitch
  if (rightout>max_volts)
 {
```

```
  rightout=max_volts;
 }
 else if (rightout<min_volts)
 {
  rightout=min_volts;
 }

 if (leftout>max_volts)
 {
  leftout=max_volts;
 }
 else if (leftout<min_volts)
 {
  leftout=min_volts;
 }

 //write output to pin
 arduino.analogWrite(RH, rightout);

 arduino.analogWrite(LH, leftout);

 text("right out: "+rightout,20,140);
 text("left out: "+leftout,20, 160);

//**************Vertical Motors******************
 int Zout;

 Zout=int(map(Z_val,-1,1,25,230))+5;
 if (Zout>max_volts)
 {
  Zout=max_volts;
 }
 else if (Zout<min_volts)
 {
  Zout=min_volts;
 }

 arduino.analogWrite(V, Zout);
 text("Vertical: "+Zout,20,180);

//******************claw control*******************
int claw;
if(claw_close.pressed())
{
 claw=84;
}
```

```
else if(claw_open.pressed())
{
  claw=172;
}
else
{
  claw=132;
}

arduino.analogWrite(clawpin, claw);
text("Claw: "+claw,20,200);


//*************arm control*****************
if(arm_up.pressed())
{
  arm=84;

}
else if (arm_down.pressed())
{
  arm=172;

}
else
{
  arm=132;
}

arduino.analogWrite(armpin, arm);

//visual interface
line(300, 150, 300, rightout-28+50);
line(290, 150, 290, (rightout-28+50)*.9+15);
line(310, 150, 310, (rightout-28+50)*.9+15);
line(200, 150, 200, leftout-28+50);
line(190, 150, 190, (leftout-28+50)*.9+15);
line(210, 150, 210, (leftout-28+50)*.9+15);
line(300,rightout-28+50,290,(rightout-28+50)*.9+15);
line(300,rightout-28+50,310,(rightout-28+50)*.9+15);
line(200,leftout-28+50,210,(leftout-28+50)*.9+15);
line(200,leftout-28+50,190,(leftout-28+50)*.9+15);

//**********sensor input**********

//for arm motion
```

```
if (arduino.digitalRead(arm_sensor)== Arduino.HIGH)
{
  text("ARM OUT OF RANGE",20,120);
  if(arm_direction)
}

//for tape measure

if (reset.pressed())
{
  distance_counter=0;
  speed=0;
}

current=(arduino.digitalRead(tape_measure)==Arduino.HIGH);
if((current != previous)&&(limiter==0))
{
  distance_counter++;
  limiter=1;
  time_start=false;
  timer=0;
}
else if ((current != previous)&&(limiter==1))
{
  limiter=0;
  time_start=true;
}
previous=current;

if(time_start)
{
  timer++;
}
else if(!time_start)
{
  speed=6./float(timer);
}

estimated_distance=speed*float(timer);

if(estimated_distance>6.0)
{
  estimated_distance=6.0;
}

distance=float(distance_counter)*6.0+estimated_distance;
```

```
text("tape measure: "+distance,20,220);

if (distance>(target_distance-1))&&(counter<600))
{
  text("OPEN CLAW!!",20,240);
  counter++;
}

}
```

Turbidity Sensor Code

```
import processing.serial.*;

import cc.arduino.*;

Arduino arduino;

PFont F;
void setup() {
  size(1550, 250);
  frameRate(50);
  arduino = new Arduino(this, Arduino.list()[0], 57600);

     F=createFont("arial",14, true);
      textFont(F, 14);
      fill(0);
    background(255);
    line(25,200,1525,200);
    line(25,0,25,200);
    pushMatrix();
    rotate(PI/2);
    text("Turbidity",50,-10);
    popMatrix();
    line(325,200,325,210);
    text("1 Min",315,230);
    line(625,200,625,210);
    text("2 Min",615,230);
    line(925,200,925,210);
    text("3 Min",915,230);
    line(1225,200,1225,210);
    text("4 Min",1215,230);
    line(1525,200,1525,210);
    text("5 Min",1515,230);
```

```
  F=createFont("arial",14, true);
  arduino.pinMode(5,Arduino.OUTPUT);
  arduino.digitalWrite(5, Arduino.HIGH);
}
int n=249, k, l;
float value, previous_value;

void draw() {

 textFont(F, 14);
 fill(255);
 n++;
 rect(95,210,40,20);
 fill(0);
 text(arduino.analogRead(1),100,225);
 k=n/10;
 l=(n-1)/10;
 value=map(arduino.analogRead(1),0,750,200,0);
 line(l,previous_value,k,value);
 previous_value=value;
 if( k>1525)
 {
  saveFrame();
  background(255);
  n=249;
  background(255);
  line(25,200,1525,200);
  line(25,0,25,200);
  pushMatrix();
  rotate(PI/2);
  text("Turbidity",50,-10);
  popMatrix();
  line(325,200,325,210);
  text("1 Min",315,230);
  line(625,200,625,210);
  text("2 Min",615,230);
  line(925,200,925,210);
  text("3 Min",915,230);
  line(1225,200,1225,210);
  text("4 Min",1215,230);
  line(1525,200,1525,210);
  text("5 Min",1515,230);
 }
 }
```