UMass Dartmouth IDEA Club

Technical Report

2012 Annual MATE ROV Competition

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This year the IDEA Club from the University of Massachusetts Dartmouth is competing for the second time in MATE's international robotics competition. As always, participation in this competition has proven very rewarding. The ROV was designed to complete numerous tasks which would simulate surveying a shipwreck site. Member-designed tools were tried and tested, redesigned and retested numerous times. Members were forced to adapt to any obstacle that was thrown in front of them; including writing professional proposals in obtaining funding. Through hard work and determination, the UMass Dartmouth IDEA club will be able to travel to Orlando, Florida and compete in MATE's international ROV competition.

Contents

Photographs

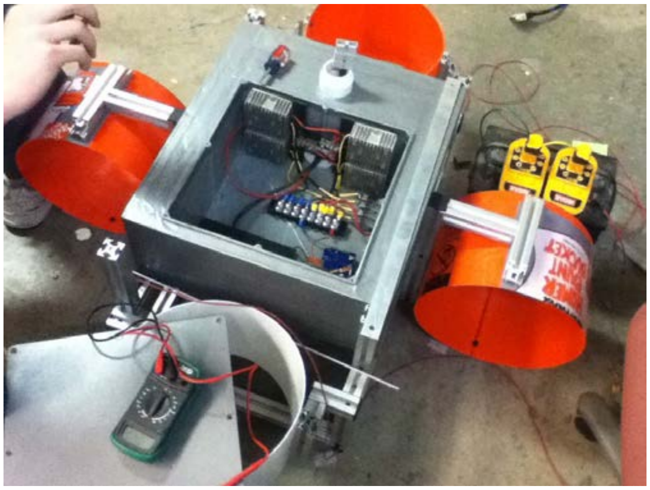


Figure 1: To the left is a top view photo of our ROV with a couple of our electronics not instead due to testing.

Figure 2: To the right a photo of our surface control box. The right monitor is displaying the image from our HD camera.

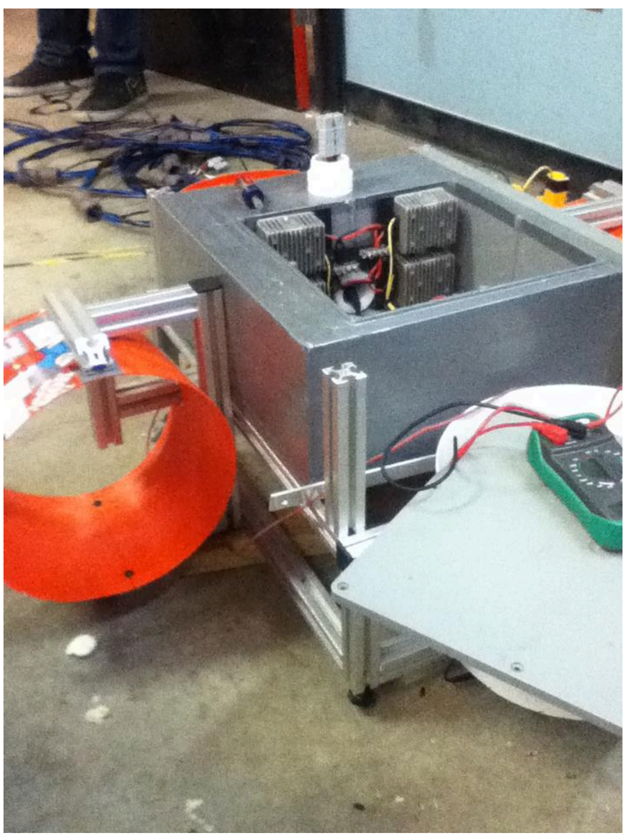


Figure 3: To the left is a side view of the ROV, minus the motors.

Budget

UMass Dartmouth IDEA Club ROV Budget Report

INCOME	Requested	Actual	Difference
ECE Department	$1,500.00	$1,300.00	$200.00
COE[3]	$1,000.00	$1,000.00	$0.00
Home Depot Gift Cards	$100.00	$25.00	$75.00
Gibson Engineering	$500.00	$500.00	$0.00
Norm	$1,000.00	$1,000.00	$0.00
Student Affairs Office	$700.00	$700.00	$0.00
Personal Contributions	$700.00	$700.00	$0.00
Other			$0.00
Total Income	**$5,500.00**	**$5,225.00**	**$275.00**

Project Expenses	Projected	Actual	Difference
Motors	$320.00	$280.00	$40.00
Blade Props	$50.00	$50.00	$0.00
Joysticks	$0.00	$0.00	$0.00
Cameras	$300.00	$200.00	$100.00
Chips	$180.00	$240.00	$60.00
Tether	$0.00	$0.00	$0.00
Frame	$50.00	$0.00	$50.00
Tools	$400.00	$350.00	$50.00
Other	$0.00	$0.00	$0.00
Total	**$1,300.00**	**$1,120.00**	**$180.00**

Project Donated Expenses	Projected Cost	Cost to us	Difference
Frame	$375.00	$0.00	$375.00
Propellers	$100.00	$50.00	$50.00
Surface Control Box	$500.00	$50.00	$450.00
Claw Materials	$30.00	$0.00	$30.00
Total	$1,005.00	$100.00	$905.00

Transportation	Projected	Actual	Difference
Flights	$2,000.00	$1,773.60	$226.40
Rental Car	$600.00	$504.00	$96.00
Hotel	$750.00	$750.00	$0.00
Shipping ROV	$200.00	$200.00	$0.00
Total	**$3,550.00**	**$3,227.60**	**$322.40**

Total Income & Expenses	Projected	Actual	Difference
Project Construction	$1,300.00	$1,120.00	$180.00
Donated Expenses	$1,005.00	$100.00	$905.00
Transportation	$3,550.00	$3,227.60	$322.40
Income	$5,500.00	$5,225.00	$275.00
Total	**$355.00**	**$777.40**	**$1,132.40**

This year's finances were a little rocky for us, this is due to our company doing multiple projects throughout the year; including a fully electric go-kart and a quad-copter. Luckily our University was very supportive of us when we were in need of funding and guidance which we considered invaluable. In addition one of our sponsors, Gibson Engineering, donated the majority of our parts for the ROV. We only needed to purchase electronics, tools, and other minor parts.

When it came to allocating our budget we relied deeply on our experiences last year. Last year we learned to make every penny count and we followed that same principle this year. As a result we utilized as much of the parts we had sitting around our work shop. In addition we would always find a use for anything donated to us. Doing all this resulted in us being able make small amounts of funding go a long way.

Electrical

Overview

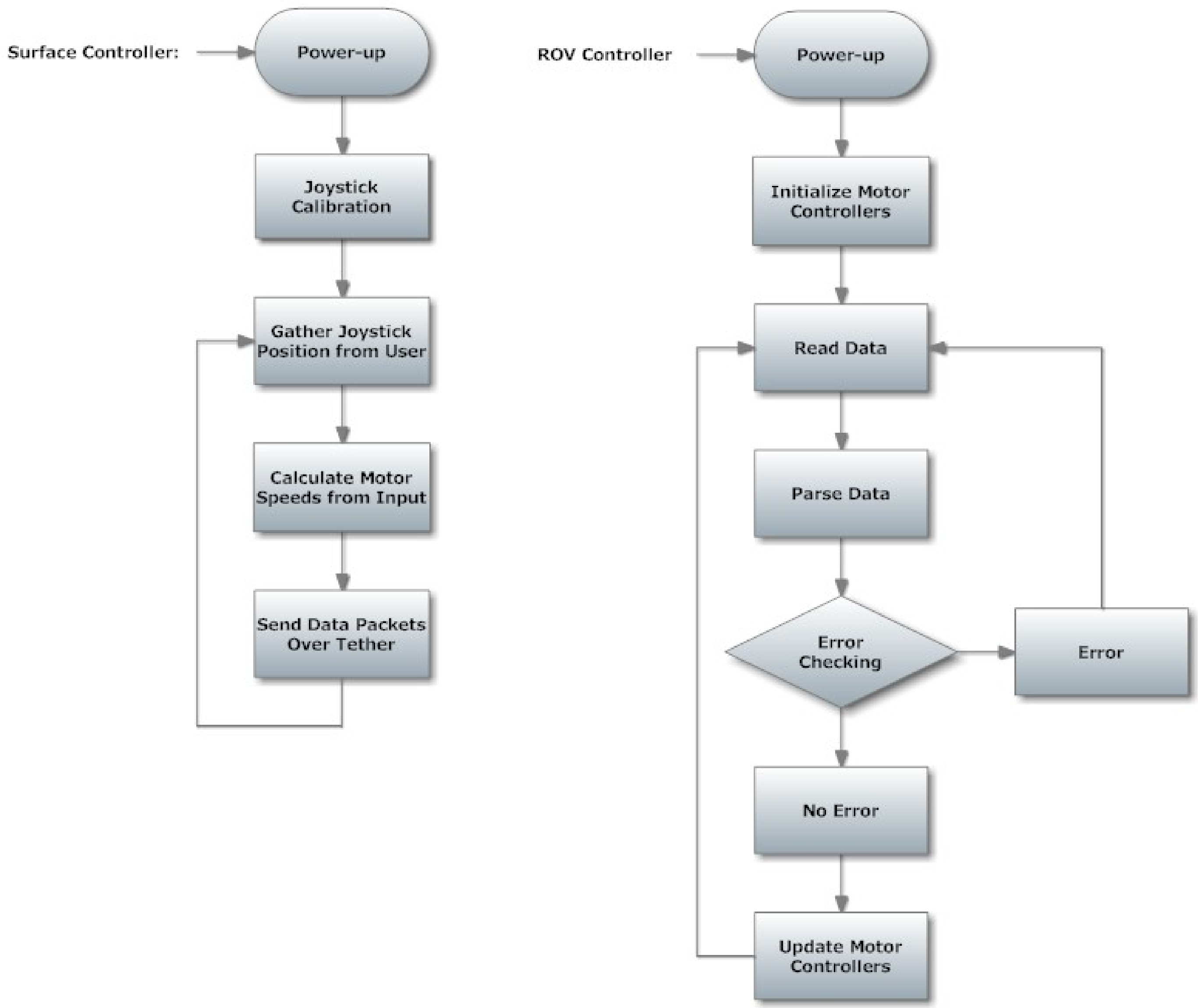
Our electronics are broken down into three main parts: Input, communication, and output. On the surface, we have constructed a control box which houses our input processing electronics. To interpret input, we chose an Arduino Uno. The Arduino platform is widely used because of its versatility and ease of use. With only a little bit of programming knowledge, a developer can create a multitude of electronic projects, limited only by imagination and budget.

The Arduino on the surface has been programmed with code to read the position of two joysticks, and calculate a motor speed and direction from that position. Then it sends a 5 byte packet through the tether to the Arduino on the ROV. The 5 byte packet consists of: 1 byte for the motor number, 3 bytes for speed, and 1 byte for parity. For example, the packet '3160/' would tell the chip on the ROV to set motor 3 to a speed of 160 (out of 180). The direction is sent within the speed, a '000' meaning full reverse, a '090' being full stop, and '180' being full forward. Once the packet is sent, the Arduino reads the next set of positions from the joysticks, and does all the calculations again, and sends the next set of packets out.

Once the Arduino on the ROV has received 5 bytes, ending with a '/', it parses the data. It extracts all the data into temporary variables, setting the motor controller indicated by the first byte to the speed indicated by the 2nd-4th byte. Before actually setting the motors to that speed, however, the Arduino performs some error checking to make sure that no packets are corrupted. This arose after the ROV displayed some erratic movements, such as setting 2 motors to full speed for 1-3 seconds while the joysticks weren't touched. This error checking method has eliminating all the erratic behaviors.

The output of the Arduino is routed through a custom made PCB that groups the pins together for easy detachment. Each motor controller is operated by two pins, the pulse pin and the ground pin. The pins on the Arduino's PCB are connected to each of these motor controllers.

Software Loop



Control Box Wiring

Our control box is equipped with four DC-DC power supplies, our logic electronics, and our motor controllers, as well as relay circuits for tools and pneumatics.

DC to DC converters

Our DC to DC converters supply power to all of our electronics on board the ROV. They are 48V- 12 V converters, as all of our electronics are 12V. We receive 48v power from the tether to terminal blocks onboard the control box, which is then split to each of the four DC to DC converters. The 12 volt power out of the converters is routed through fuses to protect against over-current to the converters. The power is then tied together to a terminal block, where it is distributed to all the electronics in the box.

Motor Controllers

The motor controllers we have decided to use are called HB-25s. These are simply H-bridges that can handle up to 25A apiece (with a 35A peak draw), and are addressed as continuous rotation servos. A servo is controlled by sending it pulses. The length of the pulse determines the angle or the servo, or in our case with the HB-25s, the direction and speed of the motor. For example, a 1ms wide pulse indicates full reverse, a 1.5ms pulse indicates neutral, and a 2ms pulse indicated full forward. Speeds in between these extremes make the HB-25s PWM the output to scale up and down the speed of the motors. The Arduino program has a servo library, which after some tweaks, integrates perfectly into our system. Sending a '0' to the library generates a 1ms pulse (full reverse), sending a '90' generates a 1.5ms pulse (neutral), and a '180' generates a 2ms pulse, for full forward.

Cameras

Cameras are mounted in a multitude of places around the ROV. The signals are sent over the tether, and are attached to switches on the control box, to be able to switch the multiple inputs to one output. We have some special cameras routed to pre-designated circuits, such as our GoPro, which is input into a computer for the task of taking measurements of the ship.

Design & Rationale

The decision to use extruded aluminum for the main foundation for our frame was fairly easy. This was because extruded aluminum would not only make it easier to alter the mounting position of any tools we use, but it was also donated to us for free. Considering we were constrained to a very tight budget the inexpensiveness of the extruded aluminum helped a great deal. This material also helped in creating a very sturdy structure to use as our base.

Other reasons we decided to use extruded aluminum was for several key reasons. These reasons are that extruded aluminum has become a standardized product available in our workshop thus allowing our team to quickly build our ROV frame and if necessary make any changes due to a change in design, advantages also include its cost to us.

The general design of the frame was firstly build around the choice of motors and the tools built off of the frame. The frame provides good support for the motors while also allowing us to disassemble it into parts for easy transportation. The frame also allows for easy access for wires to be routed from the control box throughout the extruded aluminum channels of the ROV, whether it is to motors, tools, or cameras. Since the frame and control box leave a center opening in the middle of the ROV, it provides the perfect place for a majority of our tools to be mounted. The extruded frame also made it very easy to mount the shrouds for our chosen thrusters. The amount of stability the frame provides for this year's ROV is one of the biggest improvements done to our ROV. It not only provides for more stability but also gives a much higher amount of safety.

Designing this year's ROV member Tyler Fontaine personally built four different buoyancy packages and electronics boxes for our ROV. The first design featured the use of 24lb buoyancy syntactic foam that was engineered to withstand pressures at 5000 feet which we could get free of cost. Within this foam would be the location of our fiberglass electronics box. The second design used the same electronics box but replaced the syntactic foam with a fiber glassed hallow balsa wood shell for maximum buoyancy while sacrificing strength. The third design took a slight turn on the overall design. We used a prebuild outdoor waterproof electronics box from Home depot to enclose our electronics and fiber glassed Styrofoam shell was used for the remaining buoyancy. The major downside to this design was the bond between the plastic electronics box and the fiberglass which limits the depth capabilities of the package. The final design used the same prebuild electronics box but for the remaining buoyancy we used R10 closed cell wall insulation due to its compressive capabilities and mainly its closed cell design.

To protect the control system we filled the one pipe leading to the control boxes with a type of caulking that has the ability to never fully harden completely, while still keeping a strong outer shell, which completely isolates the control box from the rest of the ROV.

Prop placement is crucial to a successful R.O.V. On our ROV we employed 4 thrusters in set of two groups of motors. The first set is our dive motors. These set of motors are used to dive and ascend through the water. They are placed in the front and back of the frame. They are placed as low as possible to lower of center of gravity. The second set of motors is the drive motors or forward and backwards motors. Theses motors are placed across from each other and at the midway point of the ROV. These motors can be independently controlled and were positioned to give us the optimal turning radius for the mission.

Challenges

One of the biggest obstacles a team can face in a development of a ROV for a major competition can stem from time constraints. For our group we had a major leadership change over the winter; this caused us to be greatly behind schedule. Originally we planned to have a complete design of the ROV by January and have the majority of our funding before the start of our spring semester. However this was not the case since we are still working on obtaining funding currently and we finalized our designs in April.

All this together has contributed to us being heavily rushed in completing our ROV, however we did learn from our mistakes. We have learned that we should stick to a stricter timeline and try not to change leadership roles. This would allow us to follow the engineering design process more closely, giving us a better experience all around.

Troubleshooting & Lessons Learned

To troubleshoot, multimeters, oscilloscopes, and logic analyzers were crucial. During testing of the electronics control system, only two of our motors would respond to input: one was glitching and twitching, and the other would just never move. After analyzing my code, I realized that the array of servo-motors was a zero-based array, yet I was using it as if it were one-based. Once this was fixed, one additional motor worked, yet the twitching motor continued. To fix this, I attached probes from a logic analyzer to the servo and communication outputs on the Arduino board we were using. This allowed me to capture the output pulses, and realize that one servo pulse line was tied to the Tx line of the Arduino, via a small amount of solder bridging the traces. Once this was fixed, all the motors would respond correctly.

After we got the motors working in general, we faced an issue concerning power-up sequences. For some reason, none of the motors would respond to input unless power was provided to the ROV Arduino before all other power was provided. We originally believed that the digital signals weren't being transmitted correctly over the long tether. Since the Arduino Mega that we used on the ROV has multiple serial ports, I modified the program on the chip to mimic the data it receives on one port, to another port which I connected to a laptop to monitor the data, checking for errors. I found that the data was being transmitted correctly, no matter which power up sequence was used. This prompted many theories and tests to be done, including adding a delay to the software upon boot, to let the other Arduino complete its calibration and start up sequence first, as well as putting in a switch to manually switch the circuits on and off, so that the chips weren't turning on at the same time. In the end, I realized the motor controllers have a protection mode, and once I toggled this mode to 'off', everything worked fine, without having to worry about a certain power-up sequence.

Future Improvements

Considering as a club we are being very constricted from major improvements because of financial issues, we do not have many major improvements that we will be doing. However, that does not mean that we have not planned out any improvements. One improvement that we are definitely considering would be the way the motor mounts are, because they are not as sturdy as we would like them. Secondly, perhaps not this year but definitely next year, we will be looking into more reliable control boxes that would not be so difficult in preventing water leakage. The tether could also use improvements, as all it is right now is wires zip tied together, with foam on the outside. We would also buy motors that weighed less, and perhaps smaller propellers, to take up less space on the ROV. Some members also feel as if the frame should be made out of a different material. Some have suggested LDPE, with channels milled into the side to guide wires through.

Reflections

David Prairie

Beyond the regular engineering aspects learned through a project of this magnitude, I personally learned a great deal of financial skills. Coming into the position of treasurer I was left with a great deal of organization to do and had to learn very quickly how to keep a strong and accurate budget. By being able to sit with professionals on campus I was able to gain the skills required in having the responsibility of all club finances.

Steven Brown

This experience has meant a lot to me. Besides meeting friends, I have learned time management, team working skills, and have gained confidence in using machinery and equipment I have never before been introduced to. Many all-nighters have driven the point of time management, and this project would not have been completed if we had not all worked together. Delegation is also crucial to a project of this magnitude, as not one person can individually complete a whole system, different aspects and parts must be tackled by different people for this to be completed.

Jazmin Rodriguez

At the beginning of this project I was excited yet nervous at the same time. It is kind of intimidating entering a group of people that know what they are doing and have the experience I had yet to acquire, but they took me under their wings you could say. To be honest I was surprised how much they trusted me with me building some of the parts and using the machinery. It definitely made me feel more confident in myself and trust myself more. I may have burnt myself a few times doing the wiring but it was worth it to say I made it. I could not have asked for a better team to work with we have the veteran, the wiz programmer, the mechanic know it all, the financial advisor who else is going to tells us to keep track of our expenses, the hard working joker, the glue which is the team leaders and the quick learning newbie. After this whole experience I have gain so much confidence in myself and my ability to become an engineer.

References

For help with electronics, Mark Whittaker from The SHARE Foundation has been a crucial source for advice. He helped us design the motor controllers, and provided technical advice when our own was insufficient.

For frame and tool design advice, Robert Flynn from Taco helped guide us in the right direction when designing.

Al & Betty Mahoney helped explain some techniques of machining, as well as provided us with some precision laser-cut claws for our tools.

Acknowledgements

MATE Center

Student Government Association (SGA) – The SGA provided our club with enough funding to start the construction of the ROV and they also provided the majority of finances needed for travel. The SGA is a place where any student can voice their opinions and concerns.

Mission Statement:

1. To act as the students' liaison to UMASS Dartmouth, the UMASS system, the Commonwealth, The Chancellor, and the Board of Trustees.

2. To provide guidance in cooperation and understanding among the students and their organizations.

3. To provide an outlet for student views and concerns

4. To promote student rights, views, interests, and welfare by recommending appropriate policies.

5. To endeavor to provide adequate funding for student needs and interests.

College of Engineering (COE) – When we were in a tight bind in late April the Dean's office provided us with a donation, matching all external donations. The College has approximately 1,000 undergraduate and 300 graduate students. The faculty consists of 65 full time professors with degrees from some of the most prestigious universities in the US and abroad. Departments operate modern teaching and research laboratories and state of the art computer facilities.

The Home Depot – This Company provided one hundred dollars in gift cards to their hardware store for the construction of the ROV. The Home Depot is a home improvement store that carries many of the components needed during construction.

Personal Contributions – Each member attending the competition has one hundred dollars of their personal money to attend.

Gibson Engineering – Gibson Engineering, Inc. is a leading solutions provider for world-class manufacturers of industrial automation products.

UMass Dartmouth Student Affairs

Electrical and Computer Engineering Department