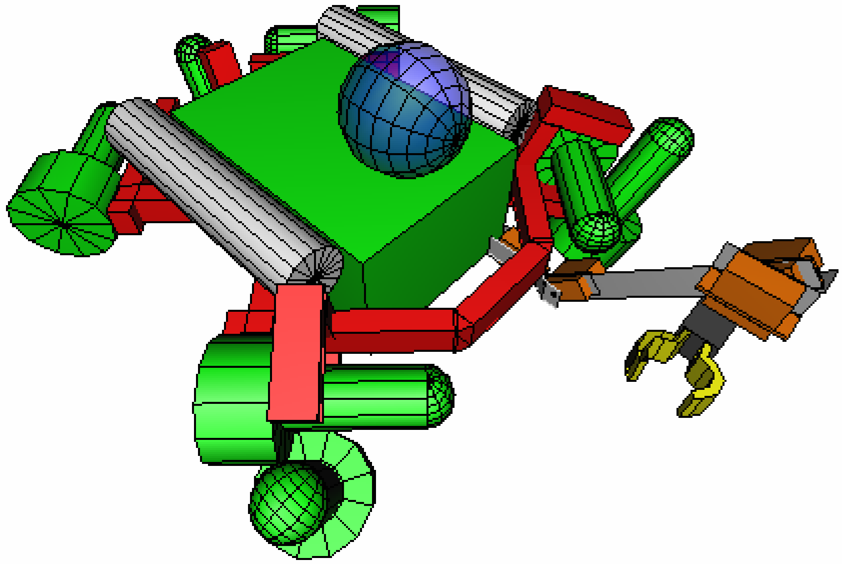

The Dolphin

Striving for Perfection Attaining Excellence

Alvin Community College

Team members

Nicolas Alvarado	Captain, Electrical and Mechanical Engineering at University of Houston, and Marine robotics at ACC; graduating 2007
Adam	Mechanic, Marine Robotics at ACC: graduating 2006
Chase	Programmer, Computer Main. At ACC: graduating 2006

Team mentors

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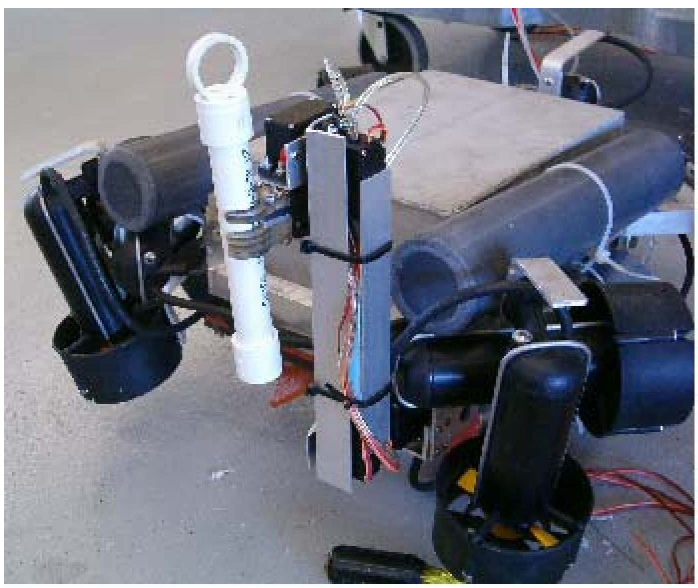
Abstract

Often there is a need to travel beyond the limits of our own frail bodies, this need arises when the threat to life is high or the task to costly possibly a size restriction or a long term requirement. This is the venue to which Remote Operated vehicles (ROVs) flourish; although still relatively young the submersible variety has quickly become a main stay in the oil and scientific community. This development has created a need for bigger better more able machines, but there will always be a need for more compact, maneuverable, and economical vehicle. The current competition scenario is an excellent example of the future needs the industry will face. To this end Alvin Community College (ACC) has plunged developing an advanced ROV specifically designed to be compact and maneuverable, to accomplish many different tasks and objectives, and onto which different payloads can easily be interchanged. The outcome is The Dolphin weighing in at a rather hefty 13.2 kg, rated to an estimated 100 meters in fresh or salt water, traveling at a speed of 7.43 km/h and nearly unparalleled agility.



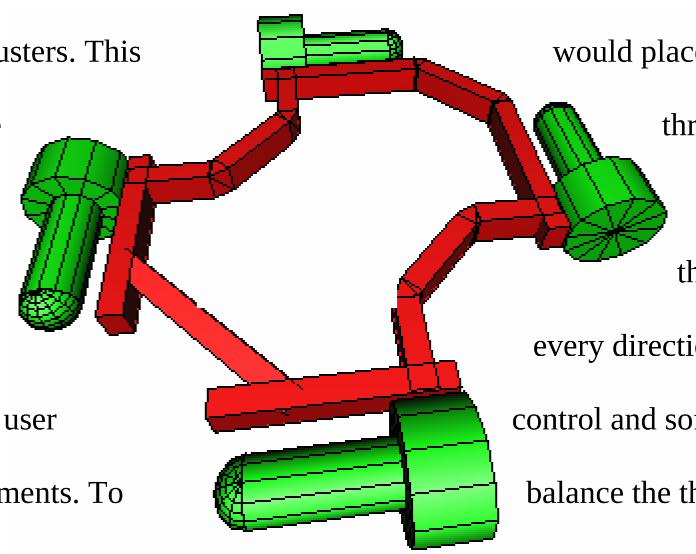
Design Rationale

Not wanting the use leak prone amp hungry bilge pump motors that are so commonly used the team set out to first find reasonably priced thrusters or design our own. A preliminary thruster design incorporated a magnetic coupler to transmit rotational motion from a cylindrical magnet within a sealed container to an outside ring magnet on which propeller blades were attached thus eliminating the need for any shaft seals. Although a viable solution a cost based analysis showed an estimated price of $200.00, a prototype magnetic coupler was constructed but this proved to be a long tedious chore. The project was dropped however when SeaBotix offered a 50% discount on refurbished SBT150 thrusters though without the internal speed control unit. At the discounted price of $297.50 the extra expense was worth every precious second of time saved.

Layout

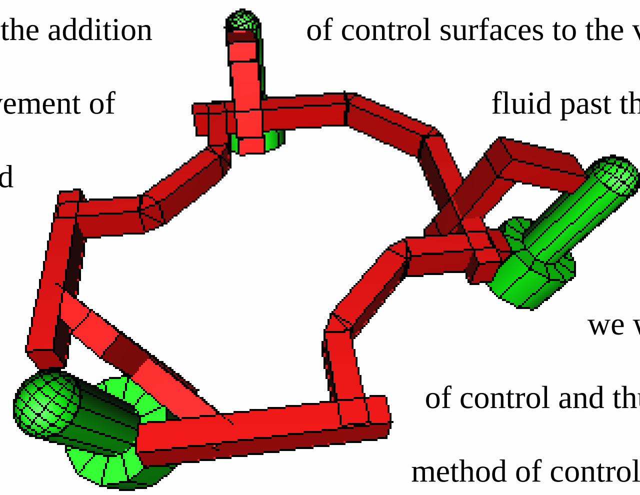
With thrusters en route the team turned its focus to the ROV's layout, the initial design came about quickly with team members, mentors, and instructors all offering input as the design was hashed out in a cad program called AC3D purchased from INIVIS. Having a 3D representation that was quickly and easily adapted to the group's vision proved to be an invaluable asset, as the entire ROV was designed in a single session.

Due to the size restrictions and the need for fine motion control, the ROV would require the three basic horizontal degrees of freedom found in most small commercial ROVs, requiring a minimum of three thrusters. This would place two thrusters facing aft and a single thruster along the transverse axis. Although an efficient use of thrusters the ROV contains a bias to every direction of motion it therefore complicates user control and software compensation in very delicate movements. To balance the thrust output we adopted a vectored thruster setup that would require four thrusters, each



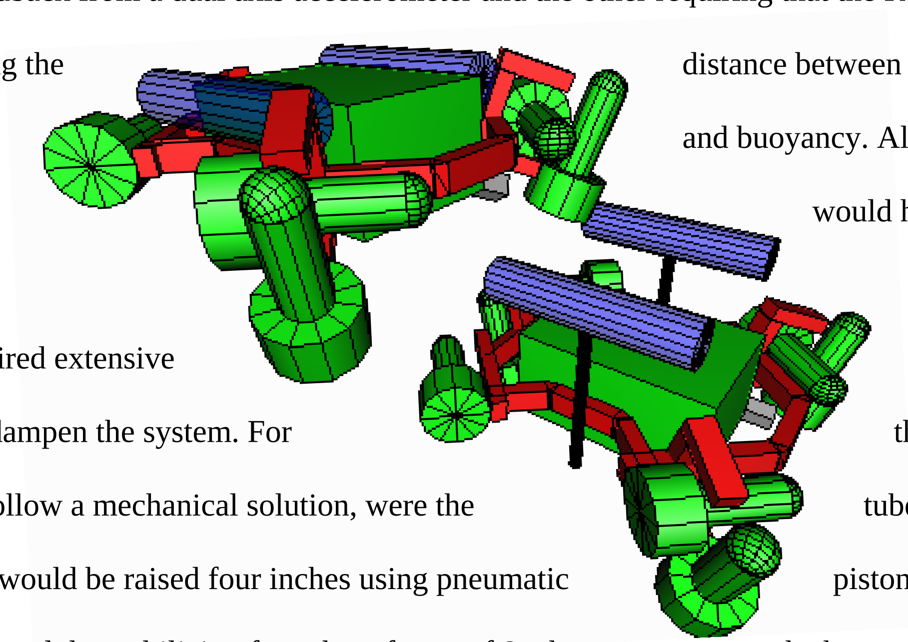
arranged at the corners of the ROV as depicted with the green thruster within the picture. Each individual thruster produces a bollard thrust of 28.44 N therefore producing a theoretical thrust, at zero speed of advance and full rpm, of 80.44 N

It was concluded early on that the majority of time would be spent traveling the 13 meters to and from the bottom. To compensate for this loss of time the ROV was designed to travel this by pitching down and using its four horizontal thrusters. This in turn created the need for at least two vertical thrusters or the addition of control surfaces to the vehicle. The control surfaces require the movement of fluid past the device to operate; the ROV therefore would have to be traveling forward before it could pitch up or down. The environment in which we were to work is not conducive to this type of control and thus we decided to use the multiple thruster method of control. Furthermore the ability to pitch would require an inherently unstable ROV or we would encounter considerable resistance in maintaining a specific pitch angle. To compensate for this it was decided to move the center of buoyancy and the center of gravity to within a half inch of each other, but this created another problem, as the ROV would loose stability fore and aft but also port and starboard. The careful placement of buoyancy centered along the transverse axis would to an extent counteract the instability but not sufficiently enough to rely on solely two vertical thrusters. The use of three thrusters, two placed at the forward corners and the third centered at the aft, allows us to compensate for instability in any direction and give us freedom to move the buoyancy where it is needed.



Dynamic Stability

The complex issue of stabilization posed a considerable threat to the pilot's ability to maintain a position in initial water tests, to compensate two solutions were devised one involving sensor feedback from a dual axis accelerometer and the other requiring that the ROV be capable of changing the distance between the centers of gravity and buoyancy. Although the former would have been far simpler to implement had it not required extensive derivations to critically dampen the system. For this reason we chose to follow a mechanical solution, were the tubes that provided buoyancy would be raised four inches using pneumatic pistons as depicted. This improved the stabilizing force by a factor of 8 when the buoyancy tubes were deployed, an incredible improvement from the pilots stand point.



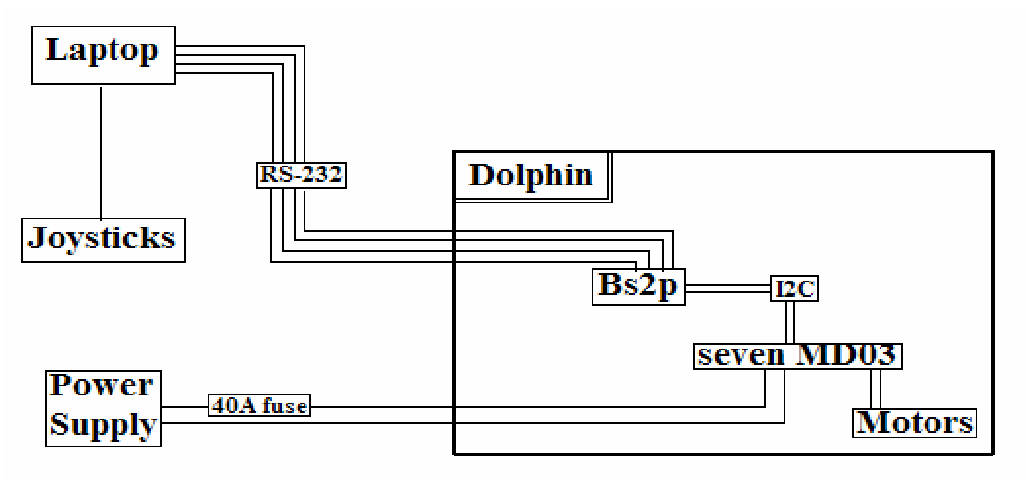
Video

To more comprehensively perceive the surroundings, CCD cameras were chosen that could easily be mounted to a small pan and tilt (P/T) device held within a clear sphere. In this manner the pilot could monitor many different portions of the ROV as he traversed through tight spaces or around delicate items. Two P/T

cameras were planned, one for the top placed slightly forward and the other below and back. Acquiring the optically clear spheres however turned out to be very difficult as many plastic companies will only sell in bulk or only carry colored items. In the end we had to settle for two hemispheres which created a band of obstruction. At the time of writing all that was left to do was glue the other half of the 100 mm sphere into place, as seen in the photograph.

Surface control unit

To control the ROV we decided the most robust solution was a pair of joysticks a laptop computer and an onboard microcontroller. A program was written using Visual Basic that would read the joysticks by calling on DirectInput, perform the required calculation and send the

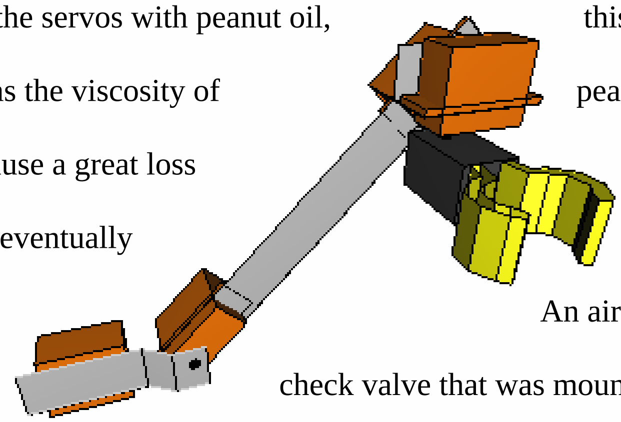


solutions for each motor via an RS-232 cable down to the ROV's internal microcontroller. The microcontroller, a Basic Stamp 2p24 from Parallax, INC, checks for signal loss or errors and only then sends the data to each of the motor controllers, MD03s from Devantech, Ltd, via an "I" Squared "C" (I2C) bus. The

Basic Stamp 2p, although simplistic in comparison to some other better known microcontrollers, offers extreme ease when programming, which offsets the difficulty associated with developing a program for Microsoft Windows and DirectX. The biggest limitation of our control unit is the limited ability of the ROV's onboard microcontroller, which will be replaced shortly after the competition. Overall performance has far exceeded our original expectations, with thruster speed updates at up to 45 times per second.

Challenging

The arm presented a considerable challenge as the ROV was not only designed for the competition but also to expand the ACC marine robotics program with a versatile and compact vehicle that would require little or no modification for other tasks. The decision was made to create an arm with at least three degrees of freedom but the final design contains four plus the gripper function. The arm uses standard servos and there in lies the problem as these proved to be exceedingly difficult to water proof at depth. Although we have successfully tested one method to a depth of 1.5 meters this is utterly unacceptable. To increase the depth we attempted to pressure compensate the servos with peanut oil, this created another difficulty to over come as the viscosity of peanut oil is remarkably higher then that of air cause a great loss in speed and torque output. The solution we eventually adopted was to compensate with air. An air line would run down to a tank equipped with a check valve that was mounted on the ROV. Air will constantly be pumped into the tank and if the pressure exceeds that of the outside water pressure the check valve opens but then closes once it drops below. In this way an approximately equivalent pressure is maintained within the tank and the outside water pressure, from this any



other enclosure might be pressure compensated for by simply running an air line to it. To date this technique has not been fully tested but we expect to finish within the next week.

Improving

Many planed items never made it into the ROV mostly due to time constraints, one of which was the autopilot function. The autopilot was integrated into the initial programs directing the ROV, but a symptom referred to as oscillation was a constant problem. The solution was calculus based functions which slowed the ROV response time to nearly three quarters of a second which was entirely unacceptable. This would have improved had we used a more advanced microcontroller onboard the ROV, which is planned for install on a later date. The ground work was also laid to allow a depiction of the ROV to be drawn into the control software on the laptop indicating pitch, roll, depth, and heading using the autopilot sensors plus an additional accelerometer, compass, and a pressure sensor for depth. This telemetry feedback was again omitted due to lack of time but will eventually find its way into The Dolphin.

Learning

The project taught many things not commonly found within the school environment, most notably about team work. Although it was Murphy’s Law that took the spotlight, every thing from leaks and fractured aluminum to computer crashes and magic black smoke from over voltage. We learned the importance of testing every component separately prior to as a whole. The importance of over engineering, as it is the only defense to the Law. That caffeine is an asset within the lab, along with team members and mentors who act as sounding boards. The two teams in friendly competition within the school also proved very beneficial as it added motivation along with the free exchange of ideas between the two groups. Dedication is the most effective solution to any problem.

Technology Advancement

Space represents the largest totally unexplored region known to man, and until our current level of advancement improves it will stay that way. Fortunately for us we have begun, on a smaller scale perhaps, with the development of more and more advanced robots, AUV, and ROV that will one day open the door to our universe. The current generation of students represents the future and what better way to give it a nudge in the right direction than a competition, motivating students to find unique solutions to problems they may one day have to solve. ROV technology is still in its infancy, but we have seen huge leaps forward in recent years. Many of the issues faced in designing an underwater vehicle mirror those of the space worthy. Communications, seals, propulsion, telemetry, manipulators; all of these are found on both and although differences may exist the technique for solving these will always be the same. The increase in computing power is plowing the way for subsequent improvements: fiber optics have entered the field, pushing data exchange to unheard of rates, thrusters have become marvels of efficiency, manipulators are easier then ever to use, multi-beam sonar recreate a 3d enviornment, and you can find vehicles rated to full ocean depth. What is in store for us is left to us to develop, advancement does not come overnight it requires hard work and sacrifice, the kind of things learned with programs like these.

Conclusion

Nothing we ever did was good enough and the team trudged on improving every aspect until the end, exhausted mentally and physically we found something incredible. The Dolphin represents the best that ACC can produce; everything about it exceeds initial performance predictions. A depth of 20 meters was our goal we hit a 100, speed was to be two knots we topped out at four, we have two pan and tilt pressure compensated cameras, a retrieval arm approaching the dexterity found in full size ROVs, and an exceptional power to weight ratio. The Dolphin is easily deployable by a single person and averages a total current draw at 24 volts of 8 amps and can easily last 24 hours on a pair of deep cycles. One of the ROV’s biggest assets is its expandability; by simply replacing one conduit connecter with another one can replace accessories for different tasks. Another important aspect is the dynamic stability system, which allows for two different flight modes. Furthermore all you need to pilot the ROV is at least one T.V., a laptop, two joysticks, and a suitable power supply. Strive for perfection and you will find yourself at excellence; the Dolphin is not perfect but its proven to be and excellent ROV.

Expenses

Product	Price	Quantity	Total
.125 x 3/4 x 48" Al flat bar	$7.49	1	$7.49
1 1/4" PVC Pipe 10'	$3.59	1	$3.59
1/8" Polyurethane Hose (500ft)	$91.50	1	$91.50
10" x 2 1/2" Sealed Polyethylene pipe	$6.20	2	$12.40
4" Clear acrylic dome	$6.40	4	$25.60
48" x 3/4" Al Square tube	$8.54	2	$17.08
5" x 2 1/2" Sealed Polyethylene Pipe	$4.35	2	$8.70
BS2p24 Micro Controller	$79.00	1	$79.00
Color CCD Camera	$65.99	2	$131.98
Cyborg evo Joy Sticks	$39.95	2	$79.90
GM16- Bertsch Gear Motor	$5.75	4	$23.00
HD servo Hinge	$0.30	4	$1.19
MCV-1 Check Valve	$3.95	1	$3.95
MD03 - 50V 20A H Bridge Motor Drive.	$82.08	7	$574.56
MsC hardware	$50.00	1	$50.00
Nylon Snap rivets	$3.95	1	$3.95
SBT150 Thrusters	$297.50	7	$2,082.50
Servo Wire (25ft)	$0.11	25	$2.63
Servos Hitec HS-331	$8.51	5	$42.55
SRR- 05-4 Cylinder	$21.25	2	$42.50
SSC-servo Controller	$39.95	1	$39.95
		Sub Total	**$3,324.02**

Donations-Previously owned

Donations			
2 x 55 gal stainless barrels, 50 lbs misc lead	Midwest Steel, Inc.	$321.00	
3 x 20 AWG of 1000 ' spools of wire	Midwest Steel, Inc.	$30.00	
3 x relay circuit modules, brass tubing connectors	Midwest Steel, Inc.	$30.00	
5 x Small Thermistors	Quality Thermistor, Inc.	$300.00	
6 blocks of delrin, large sheet of rubber gasket	Midwest Steel, Inc.	$30.00	
8 1/2" x 11 1/2" x 3/8" Lexan Sheet	Midwest Steel, Inc.	$12.88	
9 x misc spools of cables and wires	Midwest Steel, Inc.	$110.00	
Al Angle, (brass, plastic, stainless) gears	Midwest Steel, Inc.	$30.00	
Al Angle, Hardware, 2 x 10" Chop Saw Blade	Midwest Steel, Inc.	$40.00	
Al strips (assorted), connectors, gears	Midwest Steel, Inc.	$40.00	
chrome shot	Midwest Steel, Inc.	$50.00	
Flexible Tubing, misc hardware, connectors	Midwest Steel, Inc.	$15.00	
Hand-Truck, 2 wire spools, misc brass hardware	Midwest Steel, Inc.	$65.00	
Hydraulic piston rings	Midwest Steel, Inc.	$1.00	
Neoprene gasket material	Midwest Steel, Inc.	$7.78	
Pressure Tank Lid - Fabricated	A & S Machine Works	$120.00	
Sealed Plastic Tubes (various sizes)	Plastic Specialists, Inc.	$150.00	
Squeegees, mops & handles, plastic tubing	Midwest Steel, Inc.	$100.00	
Stainless tubing, Hardware, stainless rods	Midwest Steel, Inc.	$80.00	
Terminal Strips, copper bus bars, Standoffs	Midwest Steel, Inc.	$20.00	
Welding	Formers By Ernie	$400.00	
	Sub Total	**$1,952.66**	
Previously Owned			
24 AWG-6 Sheilded (80ft)	$0.15	80	$12.00
Axion 10" LCD TV / DVD	$399.00	3	$1,197.00
Devllopment Board	$64.00	1	$64.00
		Sub Total	**$1,357.00**
			$6,633.68
			-$3,309.66
		Total Cost	**$3,324.02**

Acknowledgements

Special thanks to our sponsors and mentors

MIDWEST STEEL
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Quality Thermistor, Inc.
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A & S Machine Works

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281-218-6220

Plastic Secialists Incorporated
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psifabricators.com

FORMERS by Ernie, Inc.