Portland State University

2009 R.O.V. Team

R.O.V NAME:

The Knarr

CLUB NAME:

The PSU Physics Club

TEAM MEMBER(S):

Amen Kester, Major: Physics & Mathematics, Graduation Date: Spring 2010
Arthur Aldrige, Major: Chemistry, Graduation Date: Spring 2010
Joshua Wilson, Major: Physics, Graduation Date: Spring 2009
Sharr Smith, Major: Physics, Graduation Date: 2010
Stephen Plachta, Major: Physics, Graduation Date: 2012
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MENTOR(S):

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INSTRUCTOR(S):

Dr. Erik Sánchez: Associate Professor of Physics

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Abstract

An underwater Remotely Operated Vehicle was constructed: its frame and ballast tanks were made of commercially and easily available components; its six thrusters were 0.526 L/s bilge pumps, oriented to provide all directions of motion; and a neutrally buoyant tether was used to carry electrical signals to the ROV from a dockside power source. The completed vehicle was brought to a regional competition in which it demonstrated its capabilities, successfully qualifying for an international competition.

Photographs of the Knarr

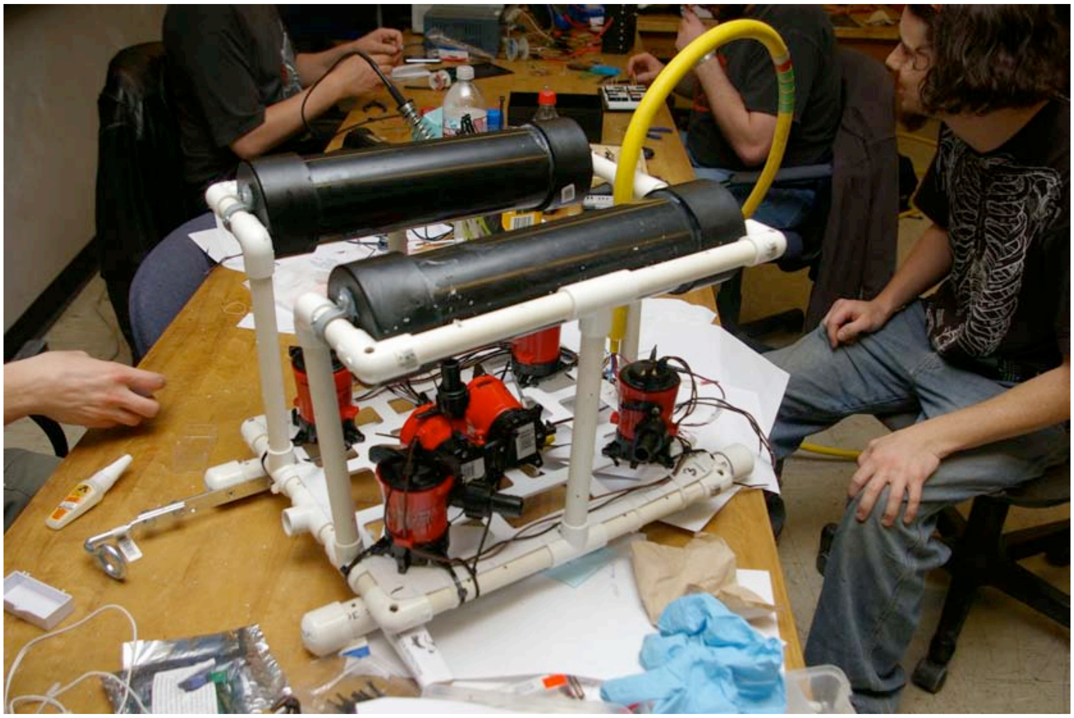

Figure 1: The Knarr, assembled

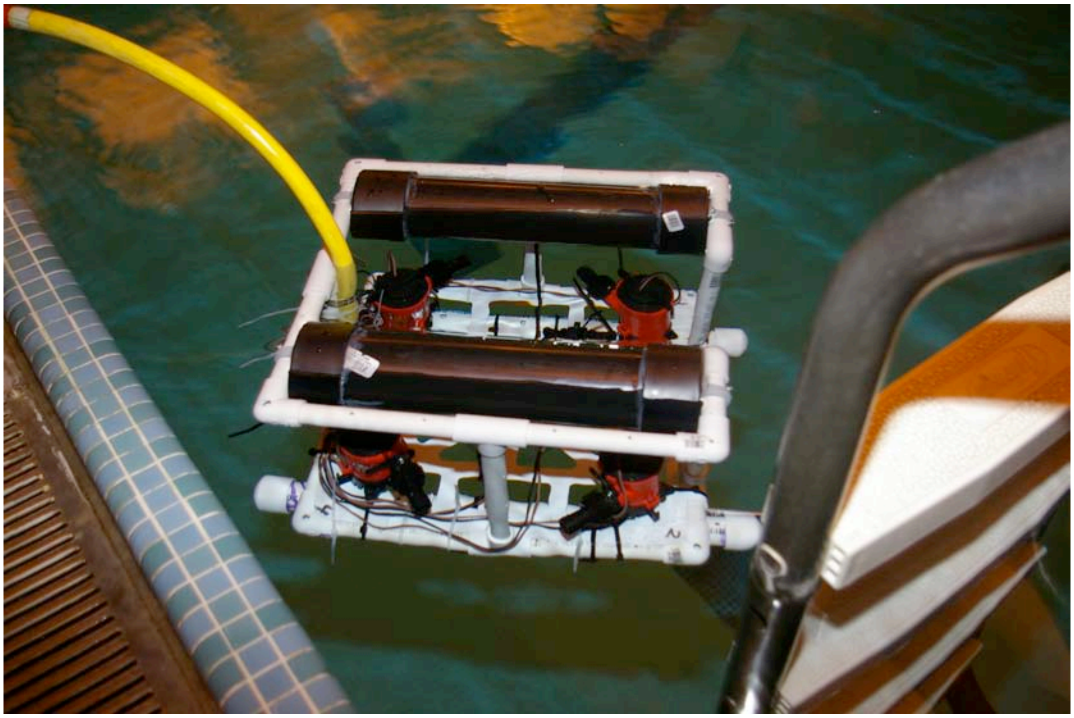

Figure 2: The Knarr, in the water

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Expense Sheet

Item	Cost
Two-blade propellers	$15
Parallax Propeller microcontroller	$30
6x Johnson Pump 3250 bilge pumps	$57
3x Ebay "China Special" peep-hole cameras	$60
4x Hitec HS-805BB high torque servos	$160
PTK25-D48-S12 48V-12V regulator	$6.50
2x Logitech Dual-action Gamepads	$50
LT1339 48V-12V buck regulator circuit	$30
LM338 12V-6V regulator circuit	$3.66
Maxim MAX3232 RS232-TTL circuit	$6.94
PVC pipe and fittings	$50
2x Project boxes	$12
Total	$481.10

Electrical Schematic

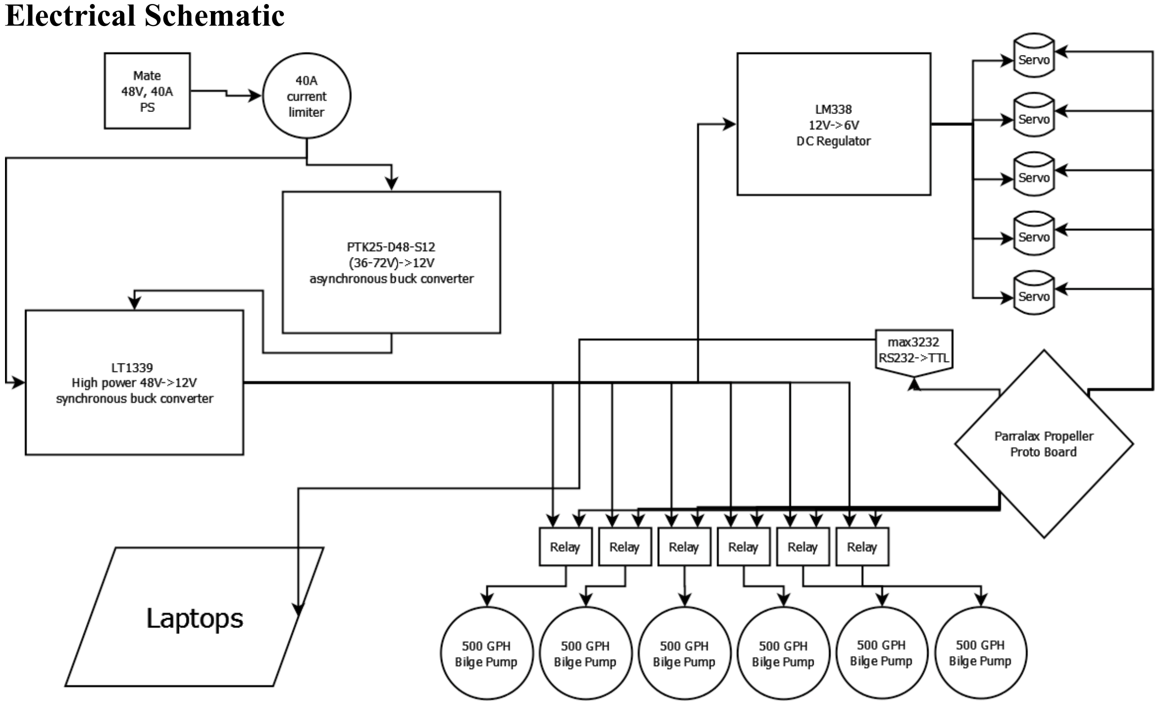

Figure 3: Electrical Schematic

Software Discussion

Ubuntu Linux[1] was chosen as the operating system for our control computers for its flexibility and stability. The software control algorithms for the propulsion system and robotic arm servos were developed in C using the Unix standard library for serial I/O and the Simple DirectMedia Layer[2] video game development libraries were used to interface with the gamepads.

The control algorithms for direct servo and motor control by the Parallax Propeller microcontroller were written in the Spin language, which the programmer was unfamiliar with. Several open-source modules were used, including the Full Duplex Serial[3] and the Servo32v5[4] for serial communications and servo control respectively, which were found at the Parallax Object Exchange.

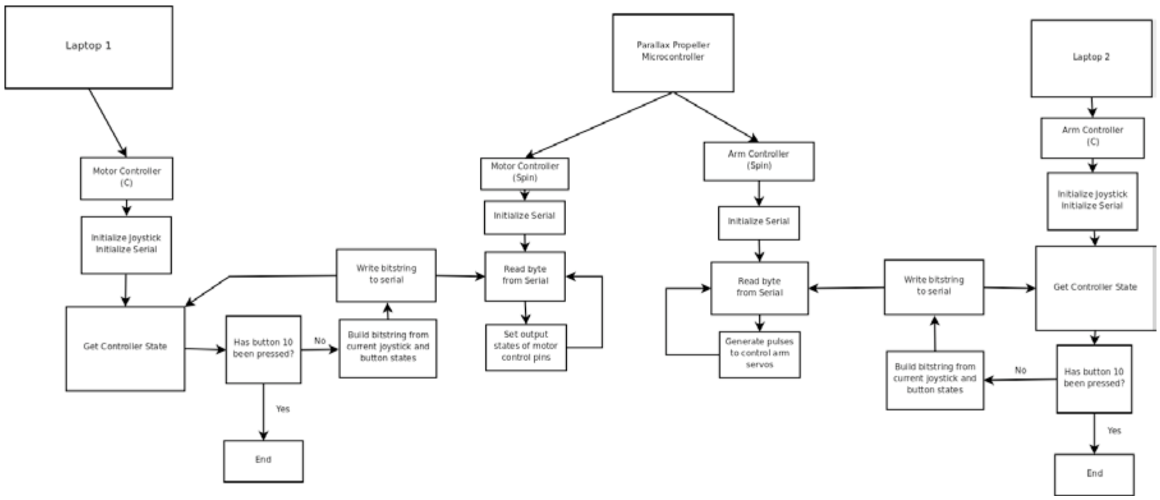

Figure 4: Software Diagram

Design Rationale

The final design for our R.O.V. was a long process that encompassed two main obstacles that we had to overcome. The first was how much time we had to actually build and test the R.O.V., and second how were we going to be able to obtain enough funding to actually build our project.

The amount of time that we had was based on how fast we could decide on a design that would we could realistically build, and cover the cost of the parts. We tossed around numerous different ideas that we all possible, but not financially. So after two terms of brainstorming we decided on a basic design we found in a book[5], and figured we could just add things to it that we needed for the competition.

The funding for our R.O.V. was whatever we could pull together from our own pockets, and parts that we could get from the physics labs on campus. We didn't have any sponsors, nor were there any grants that we could obtain.

From there we added all the components we wanted by buying individual pieces and then modifiying them so they would do what we wanted. Some of these individual pieces that we got were Bilge pumps (cheap but extremely effective), PVC piping, servos, and CCD cameras (that we waterproofed ourselves). After we obtained these things we were left with a budget that let us get all the electrical stuff we wanted without having to worry about the cost. We also got things donated as well like a computer, tether, and we received donations from a couple of local electronic stores. So in the end our main idea was that we would fabricate what we could, and use whatever was available to us so that we would stay within our budget for this project.

In the end our main goal was to just be able to complete this project and compete in the international competition, while overcoming the road blocks in our way. This was our schools first year in the competition so we had to start from scratch, and we had nothing really to start from except for our imaginations. Even though our design is pretty basic it is easy to upgrade, and improve on, which will give next years team a great head start on the next competition.

Design Challenge

While we've encountered a variety of challenges in this project, high current DC/DC power conversion has proven to be the most technically challenging. Design specifications for the 2009 MATE ROV challenge seem innocuous to the uninformed observer. However considering the low budget, workshop nature of our design efforts, efficient conversion of the provided 48 V DC power source is non trivial.
Linear DC/DC conversion while technically simplistic is plagued with low efficiency and excessive weight. Even assuming dry side power conversion and accepting the potential voltage drop across a roughly 20 m tether, the size and mass of such converters are logistically unappealing.

Asynchronous DC/DC buck regulators are dramatically more compact, enough so that wet side power conversion becomes physically feasible. However with typical conversion efficiencies not exceeding 75%, non-trivial amounts of power are dissipated as heat. Considering the size of constituent IC components heat flux in high current applications quickly overwhelms any size advantage.

In particular our efforts to implement a viable power conversion circuit under the time constraints imposed by the regional qualifications deadline and compounded by a significant project management failure necessitated a compromise in power delivery. Four self contained off the shelf V-Infinity PTK25-D48-S12[6] (36-72 V)->12 V asynchronous DC buck converters sourced from Surplus Gizmos were utilized for regional qualification. Each converter is capable of outputting a modest 2 A at 12 V, while our propulsion system is composed of six 500 GPH bilge pumps with a nominal current consumption of 2.5 A at 12 V. Fortunately control semantics constrain us to running no more than three thrusters simultaneously, perilously close to but still below our theoretical power capacity. Ideally due to the small conductor gauge of our initial tether we would have liked to integrate power conversion on the ROV. Ultimately we were forced to compromise, implementing our power conversion circuit dry side, thus suffering an unquantified though certainly significant voltage drop across the tether. While our thrust generation was sub-optimal the non-timed nature of qualification allowed us to slowly but successfully complete the required tasks.

Synchronous DC/DC buck converter designs have been steadily improving in efficiency though much of the development has been driven by embedded systems design and so lack focus on high current delivery. Relatively recent design advances, including more sophisticated derivations of basic synchronous buck converters have become available and present themselves as nearly ideal solutions to our design goals. Specifically we've elected to implement a slightly modified reference design from Linear Technologies based on their LT1339[7] high power synchronous buck converter. In reference form their design notes specify a 48 V to 5 V converter capable of delivering a sustained current of 50 A, with trivial modification this design is quoted as being able to deliver 960 W, maintaining 97% efficiency, from either 36 or 48 V source outputting 24 V. Simple component substitution from the reference design provides us a very compact and highly efficient 48 V to 12 V DC conversion system ideal for integration within the confines of the ROV platform.

Skills Gained

During the construction of the ROV for the regional qualifying event the more senior members of the team had ample opportunity to improve their leadership and motivational skills, while all members improved their methods of circuit design, analysis, and construction. Soldering techniques were also greatly improved, and team members were given the opportunity to use the machine shop to modify or customize parts and components.

Future Improvements

The following upgrades are slated for a future design revision:

- Use of the Flexiforce Sensor to determine depth
- Use of the Hitachi HM55B compass module to determine cardinal heading
- Use of the Hitachi H48C Tri-axis accelerometer to determine roll and pitch
- Use of an H-bridge and DC motor driven counterweight to control pitch
- Implement pneumatic ballast system to control buoyancy and roll
- Integrated video display with sensor data overlay
- Pulse width modulation based throttle system
- Increase thrust by using more powerful motors

Submarine Rescue System: The US Navy's SRDRS

Recently, a new submarine rescue system was fabricated by the United States Navy. Called the Submarine Rescue Diving and Recompression System (SRDRS), the craft is capable of rapid response to submarines in emergency situations.

The SRDRS design includes four components: the Assessment/Underwater Work System (AUWS); the Submarine Decompression System (SDS); the Pressurized Rescue Module System (PRMS); and PRMS Mission Support Equipment. The entire system is capable of being deployed either by air or by ground to locations anywhere in the world. Vessels of opportunity (VOOs), military or commercial craft with adequate capacities, can have components installed on board to act as bases of operation for the underwater aspect of the rescue missions.

In a rescue, the Pressurized Rescue Module (PRM), nicknamed Falcon, is used to recover up to 16 personnel per trip, who are then transferred to the SDS for controlled readjustment to atmospheric pressure. Falcon can be used to return up to 155 personnel to the surface from a maximum depth of 609.6m.

Figure 5: Falcon (Pressurized Rescue Module). Credit: http://www.navy.mil

Falcon is controlled via a tether from the VOO. It has an articulated transfer skirt for the transfer of personnel, which can be adjusted to mate with the hatch of a downed submarine at an angle of up to 45 degrees while Falcon itself remains horizontal.

Reflections

Constructing a Remotely Operated Vehicle involved many skills; all members of the team contributed knowledge essential to the project, and learned new things from each other. Team members worked all night two nights straight before the regional event, and most of the days as well. Josh put the frame together, then went to another important event. Art and Amen worked on getting the control interface together, configuring circuits that would work within the power requirements detailed in the competition manual. SuGeun and Stephen concentrated on wiring bilge pumps in such a way that would provide balanced thrust for all directions of motion: up, down, left, right, forward, backward, and rotation. The waterproofing of the wire connections, configuration of the circuit, and assembly of the control interface required focus and dedicated effort from each of the team members.

Despite one major setback, the realization that the control switches had an unintentional defect that turned on all the x-y thrusters if any one of them was turned on, the team rallied and came up with a creative solution: using manual control to touch the terminal ends of the wires of the pump(s) that would move the vehicle in the desired direction to the terminal posts of the power source! The ROV was completed just minutes before it was put it in the water for the first time, but all the dedicated effort was not wasted by any team member: the submerged ROV successfully navigated forward, backward, up, down, left, and right; turned without a hitch; and opened the required hatch. The feeling of satisfaction and accomplishment that came from seeing the vehicle in the water, not leaking, and moving under its own power was incredible; the team smiled, gave each other high-fives, and enjoyed the sensation of success.

Members learned valuable knowledge from each other, as well as gaining new confidence in their abilities to accomplish what they set out to do: challenges are not so daunting, previously unknown or unfamiliar areas of knowledge have been illuminated, and members are more ready to set out on their next voyages of invention and exploration.

Acknowledgements

The team would like to specially thank Dr. Erik Sánchez, without whose guidance and support, this project would not have been possible. We may have also forced one of his grad students to let us into his lab at 2 am so that we could ransack it for parts. We would also like to thank the following organizations for their donations and support:

- West Marine
- Free Geek
- Portland State University Physics Club
- Parallax
- Linear Technology
- Surplus Gizmos

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[4] http://obex.parallax.com/objects/51/
[5] Harry Bohm, Vickie Jensen; Build Your Own Underwater Robot; ISBN 9780968161005
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[7] http://cds.linear.com/docs/Datasheet/1339fas.pdf