University of Alberta
Autonomous Robotic Vehicle Project
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Abstract—**The ARVP team has continued their work on last year's AUV with the intention of developing it into a robust, expandable platform that will be capable of a broader range of functionality as compared to previous years. Lessons learned with regards to the construction of the physical platform were incorporated in new mechanical improvements with regards to sealing and ease-of-access to components. The electrical systems were further improved, further developing on the backplane topology that was introduced the previous year. In addition, a dedicated team worked to develop a functional Sonar system that can reliably acquire the Sonar pinger from the distances expected in competition. Software has been an area of steady improvement, with tuning and corrections being made with each round of testing.**

I. INTRODUCTION

MOVING FORWARD on the design that debuted at last year's compeition, AquaUrsa the Autonomous Robotic Vehicle Project at the University of Alberta has focused on correcting deficiencies in the design as well as improving on task-specific systems.

While the basic design is drawn heavily from last year's design, virtually all of the physical hardware in AquaUrsa has been re-designed for RoboSub 17. Parts that remain unchanged are the IMU 'tail' and enclosure, the forward accessory mounting plate and the standard COTS parts such as the thrusters and battery packs.

At first glance, the mechanical improvements are not obvious, as the basic appearance of the AUV remains very much the same. However, there is a significant improvement in component placement, sealing, and accessibility of the electrical hardware.

Improvements to the electrical systems include an evolution of the backplane-based connection system that was conceptualized for last year, a new sonar system incorporating its own FPGA processor, and a standardized architecture to facilitate expansion and improvement of existing electrical systems.

AquaUrsa's software systems have been largely carried over from last year's software, in a testament to the versatility of its "DisCo" software framework. The vision systems have been improved, in order to increase their effectiveness as well as to address changing competition requirements.

II. MECHANICAL

The completely redesigned hull, lids and internals represent a huge step for the ARVP mechanical team. A clear acrylic tube houses the electronics in plain view, and allows the entire electronics support tray to be removed from and inserted into the hull while fully connected. The forward instrument assembly houses a forward and downward facing camera in a clear case, two marker droppers and a resistive force sensor used in the Control Panel task. The vehicles thrusters are mounted on the end caps of the hull, as well as on resin-infused carbon fiber tubes that run the length of the hull. By mounting the thrusters on tubes, static and thrust balancing is as simple as sliding the thrusters to an appropriate position along the hull. Another longer tube holds the inertial measurement unit at a distance that is not affected by the hard and soft iron distortions created by the hull and thrusters. Four more carbon fiber tubes extend from the end caps that serve as legs to help support the vehicle when it is out of the water.

In spite of its unusually porcine appearance, the AquaUrsa platform is the most rugged, manoeuvrable and light-weight platform produced by ARVP to date. It excels in safety, easy to maneuver outside of water and within water. The hulls many tubes and

TABLE I. "AQUAURSA" KEY MECHANICAL PROPERTIES

Length	120 cm
Width	60 cm
Height	60 cm
Weight	<22 kg
Safety Factor	>2.0
Max Depth	100 m
DOF*	5

*Degrees of freedom

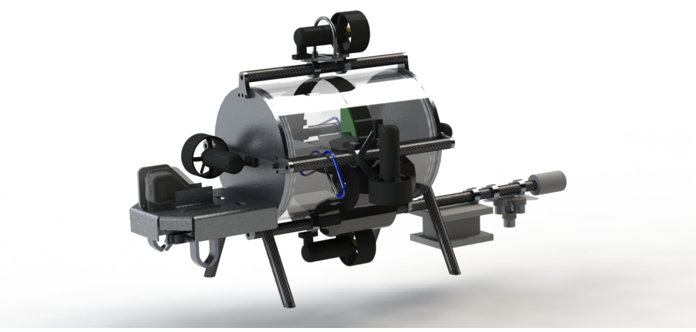

Fig. 1. Solid rendering of AquaUrsa's complete hull.

legs, along with a dedicated crane attachment, make it very easy for RoboSub officials, divers, and ARVP members to transport the vehicle.

A. Pressure Hull

The central pressure hull is the most crucial mechanical component of the vehicle, because it acts as a support for all other mechanical components as well as protecting the electrical components from the external environment. The hull is composed of an extruded acrylic cylinder sealed at each end by machined aluminum lids and o-ring seals with proper o-ring grooves. The hull and lids are tolerance to *Parker* standards to ensure standard o-ring sizes can be used and the electronics are properly sealed within the hull. The lids of the hull are flat to allow easy mounting options, but this would result in higher hydrostatic pressure in the water. This issue is solved by including carbon fiber rods within the hull that supports each lid. The back end of the lid has a removable cut out that has standard external o-ring grooves. This removable section allows easy access to the electronics within the hull. There are also threaded holes on the removable lid that allows u-channels to be attached to create a simple and efficient handle. There are also two cut extrudes on either end of the interior back lid that fits the emergency shut-down switch of the robot. The outer section of the back lid has four equally spaced tabs that ensure the interior lid is concentric to the exterior one. The front lid is one solid piece with mounting holes around the lid. There are also threaded holes that have sub-connectors that connect the electronics within the hull to the components external to the hull. There is a pipe threaded hole that contains the pressure sensor and a special cut-out that fits our camera USB connector. Lastly there are four carbon fiber rods that are mounted axially and equidistantly along the exterior. In addition to minimizing the axial compression force on the acrylic cylinder, these rods are easy access points for thrusters and external components. The bottom carbon fiber rod extends 1.8m from the end of the back lid and has a waterproof case at the end for a digital inertial measurement unit. This water proof case holds the inertial measurement unit on standoffs. One side is permanently sealed with a wire that connects to the unit and the other side has threads and a o-ring to seal it from water.

B. Electronics Tray

The electronics tray is divided into 2 distinguishable sections with the whole assembly able to slide out of the hull, as well as batteries that are able to separately slide out of the electronics tray platform. The electronic components within the hull are held vertically onto the backplane with approximately equal spacing between each electrical component. The card slots provide the support to keep the components in an upright position with the aid of aluminum side supports helping prevent any jarring to occur when AquaUrsa is set in motion. The backplane is fixated onto an aluminum platform, which are rested upon two 1-inch carbon fibre rods that placed parallel amongst each other. The batteries are kept in a 2-battery aluminum holder, with a bearing-axle assembly attached above the holder. 2 battery holders are placed below the back plane platform and in-between the carbon fibre rods with the bearings resting onto a stepped aluminum guide.

C. Frontal Assembly

At the front of the hull there is a horizontal aluminum plate mounted by bolts. This section serves as a mount for three important competition equipments:

- A transparent case holding a forward- and downward-facing camera,
- A resistive force sensor used to detect physical contact with one of the competition's "control panel" buoys, and
- Two pairs of claws that is controlled by servo motors. These pair of claws holds rocket shaped markers that helps complete two tasks in the competition, dropping a marker in the bin and picking up an object.

The rocket shaped markers are made out of polycarbonate and aluminum. They are built with four aluminum fins and an aluminum tip. The higher density of the aluminum will help the marker have a lower center of gravity and the fins will help the marker drop straight. The claws are made out of polycarbonate because it is a light-weight material and will reduce the amount of stress on the servo motor rods. The space between the straight edges of the claw is large enough to fit a PVC pipe, but small enough to ensure the PVC pipe will not slip out. The servo motors are mounted to aluminum tabs that are mounted to the frontal assembly. The camera case is constructed from bent polycarbonate for its transparency and strength. The case has a polished face at the forward and downward facing camera. This case is custom built with tolerances that allow the lenses of the cameras to be adjusted without moving the camera from the case.

D. *Hydrophone Assembly*

The hydrophone assembly consists of two parts:

- The hydrophone array
- The amplifier box

The hydrophone array is an array of four hydrophones. To optimize the reception of the pinger in the water, the hydrophones are placed equally apart from each other, less than five centimeters away from each other and in a tetrahedral shape. Each hydrophone has a custom built sleeve with a hole that is in the exact location of the wire that extrudes out of the hydrophone. Each hydrophone sleeve has a set screw to keep the hydrophone in place. Each hydrophone is attached to a platform that ensures the shape and distance requirements are met. The amplifier box is close to the hydrophone array and its main task is to amplify the signal received from the hydrophones and then send that signal to the electronics within the hull. The amplifier box is made out of three pieces. The amplifier box has two faces that have racetrack o-ring grooves and a third piece that is clamped between the two by bolts. The amplifying electronic board is held inside the sealed unit with wiring coming in and out with sub-connectors.

III. ELECTRICAL

The electrical systems architecture in AquaUrsa can be regarded as an evolution of the systems used for the previous two years. The core functionality and layout has changed very little, but over the years, various improvements have been made to increase the reliability and monitoring capability of the systems. Another area of major concern was expandability, as it is intended for this architecture to be easy to add on to. To this end, the backplane was retained and re-designed to allow maximum circuit board density with an eye towards future expansion. The slide-out electronics rack makes accessing the circuit boards a simple procedure. All the circuit board sizes and physical connectors were standardized, to eliminate concerns of loose or incorrect connections. The system bus allows all the peripheral boards access to any power or signal connections that may be required for operation.

The backplane-based approach simplifies design, improves reliability, and reduces the time required for wiring, testing, and troubleshooting, since almost every connection a given PCB might require is available on a standardized connector used by every other board.

The passive sonar system used to locate the "sample box" at the end of the course has similarly undergone a major overhaul as compared to last year.

The power systems have largely remained the same as last year, utilizing the same board design with minor changes.

A. *Backplane*

Previous ARVP vehicles typically contained a variety of PCBs, representing both COTS and custom, in-house designs. Wherever a connection between boards was required, the team took the straightforward approach of running a cable within the hull from point-to-point. Since this approach becomes very unwieldy as more boards, connections and

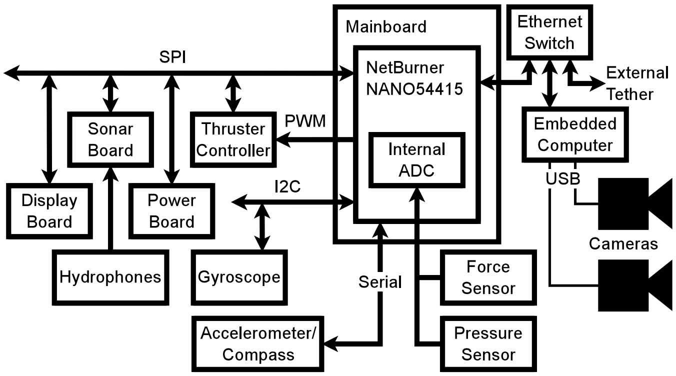

Fig. 2. Overview of electrical communication systems within AquaUrsa.

external devices are introduced to the vehicle, ARVP has developed a central backplane through which external connections, internal communications, and power are routed.

Using 50-pin card edge connectors, the backplane will provide the following connections to each connected board:

- Power voltages:
  - 12 V,
  - 5 V, and
  - 3.3 V,
- SPI data connections (MOSI, MISO and SCLK),
- I^{2}C data connections (SDA and SCLK),
- Raw PWM and direction signals used by thruster controllers,
- Generic manipulator controller pins (adaptable for use with marker droppers, item grabbers, torpedo launchers, etc.),
- Raw hydrophone signals,
- Serial UART connection,
- CAN bus connection,
- A "kill" signal activated by the vehicle's hardware killswitch.

In addition, the backplane connects to all electronics external to the core electrical system, except for the USB cameras (connected directly to the embedded computer) and thrusters (conected directly to the thruster controllers). By condensing as many internal and external connections as possible into one location, AquaUrsa's internal wiring is tidier, faster to assemble, quicker to debug, and has less risk of an inadvertent break in a connection caused by stretched or bent cables.

AquaUrsa utilizes two identical backplane boards that support daisy-chaining any number of the same board together to allow for as many slots as necessary, limited only by available internal space. The two boards are located on a slide-out rack, each containing four slots for a total of eight available slots. This is a departure from the first-generation backplane design, which arranged the cards radially around the outer perimeter of the hull. This design proved to be challenging both in design and implementation, so a simpler approach was adopted for this year's design.

B. Display Board

During autonomous testing runs, it can be difficult to verify that an AUV's mission control software is performing as designed, or where trouble might be coming from. ARVP has developed an optional display board to be used during testing. This board is mounted in a visible location, and provides detailed status information to the ARVP member handling the vehicle in the pool. Under normal condidions, the board can display the following information:

- 4x20 OLED display for textual information:
  - Current measured depth, heading, tilt, acceleration, and velocity,
  - Current task being attempted (e.g. "go through gate"),
  - Estimated bearing and distance to sonar beacon (when sonar mission is active),
  - Battery cell voltage, charge level, and discharge rate
- LED lamps for statuses:
  - SPI communications OK,
  - I^{2}C communications OK,
  - Bus voltage issues (5 V, 3.3 V out-of-range), and
- LED battery meters that provide quick verification of battery status at a glance.

Along with this "normal" information, the mainboard can also take direct control of the OLED display and show other information on a priority basis. This can provide useful diagnostic information to testers. Common, but frustrating, problems such as loose connections or dead batteries can be diagnosed immediately, instead of requiring tools, multimeters, and precious testing time to discover.

C. Sonar Board

ARVP's new sonar system is an important addition to AquaUrsa. The functionality of previous systems has been extended to create a more effective and accurate positioning system used to locate the end of the course.

AquaUrsa features a brand-new sonar system hardware design this year, yet the basic mathematical concepts of the software portion are the same. Four Cetacean Research SQ26 hydrophones are mounted in a square array in which the maximum distance between each two hydrophones are less than 5 cm. Such a setup ensures that the time difference of arrival (TDOA) between each pair of hydrophones is less than one wave period of the signal, which will simplify the positioning algorithm and computational manipulations. The hydrophone array is attached to the bottom of the vehicle with an amplifier box setup beside it. The amplifier box provides three basic functions:

- It amplifies the hydrophone signals before they are sent for processing
- It converts the single ended signals from the hydrophones into differential format, which preserves the signal qualities in transmission.
- It also receives feedback signals (via SPI) from the processing unit (which is located inside the vehicle) and adjusts its amplification index to prevent the outgoing signals from saturation

The signals go into the processing unit, which is a PCB which mounted on the backplane. This unit insists of two major portions: the ADC portion and the digital signal processing (DSP) portion. Four ADC12020s from Texas Instruments are the major components of the ADC portion and they are set to be running at 4MHz sampling rate to ensure relatively high definition results through the mathematical processing. The Spartan 6 FPGA "Saturn" Development board, is used as the DSP unit. The functionality is further described in the software section.

D. Mainboard

AquaUrsa's mainboard design is largely similar to that of its previous two AUVs, Bearacuda and SubmURSA. This board holds a NetBurner NANO54415 microcontroller core module running uClinux, that acts as the functional heart of AquaUrsa. The mainboard is directly responsible for:

- Processing analog sensor inputs from ADCs distributed throughout the vehicle:
    - Pressure and temperature sensors, and
    - Current and voltage sensors on each thruster controller and the power board, used to monitor battery status,
- Controlling the SPI, I^2C and RS232 serial interfaces used by:
    - The sonar board,
    - The OceanServer OS5000-T accelerometer/compass mounted at the aft of the hull,
    - The display board, and
    - the gyroscope mounted on the mainboard,
- Providing PWM and direction signals to the thruster controllers,
- Interfacing with the onboard embedded computer, and optionally with a tethered PC, via Ethernet, and
- Running mission control software (if the embedded computer is unavailable).

E. Thruster Controllers

ARVP's unique in-house thruster controllers are another design largely carried over from the 2012 and 2013 designs. The overall topology remains the same: Each board uses two L298 H-bridge ICs to control two thrusters, providing up to 4 A to each from a 5-cell lithium battery connected directly to the controller board. The L298s are controlled by raw PWM signals provided by the mainboard. In addition to the six PWM signals, the mainboard also provides six binary direction signals used to control the direction in which the thrusters fire. A simple network of discrete logical ICs translates the PWM and direction signals into the correct signals required to drive a thruster.

Such a simple design results not from inexperience with more complicated commercial controllers, but from too much experience! In the past, the team struggled with the reliability and power output of commercial motor controller designs, which often lacked the exact combination of features required for a given vehicle. In addition, the rare problems that do occur with H-bridges and discrete logic gates are easily diagnosed and repaired, instead of being hidden inside the complex schematics and proprietary firmware of commercial devices.

The thruster controllers are also capable of feeding power consumption data back to the mainboard through onboard ADCs. These ADCs monitor the current output to each thruster using the L298's built-in current-sense pin, as well as the terminal voltage of the battery connected to the controller, to allow the mainboard to track battery status during runs.

F. Power Systems

AquaUrsa's main power system is responsible for providing power to all vehicle components except the thruster controllers. Because of the broad range of voltage levels and power requirements of different hardware, ARVP has centralized all of this functionality into a single power board, reducing the complexity of the entire system to simplify design, troubleshooting, and repair.

The power board is supplied by a 18.5 V lithium battery, which supplies power to an intelligent power converter that steps the battery voltage down to a constant 12 V, up to a maximum power of 200 W. This voltage is further converted to 5 and 3.3 V by a separate converter that provides a combined 30 W to both rails. These three standard voltages are sufficient to power all electronics within AquaUrsa. These voltage rails are connected to the backplane through a 4-pin Molex MiniFit power connector, using the same pinout as the ATX2.0 standard. This allows the backplane to be powered by an ordinary PC power supply during bench testing.

Like the thruster controllers, the power board is also capable of reporting the battery terminal voltage and load current to the mainboard through an onboard ADC.

IV. SOFTWARE

The software systems in AquaUrsa operate on a framework called "DisCo," developed at the Department of Computing Science at the University of Alberta. The aim of DisCo is to provide an effective, modular and adaptable communication framework for software components of robotics systems. Adaptability is the key feature of AquaUrsa's software system. It is based on a number of independent components that communicate using small packets of information, making it possible for components running on different networked devices to inter-operate as easily as those running on the same device. The software components are typically distributed between the microcontroller, embedded computer, and an external development computer, but can be moved from one device to another as competition conditions change.

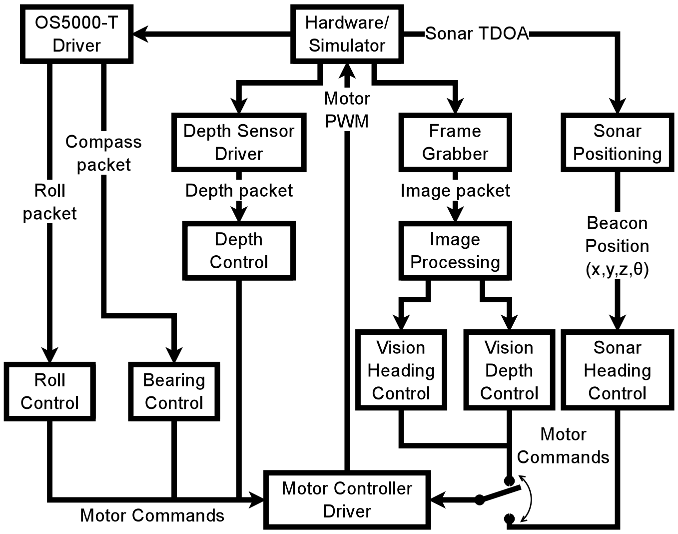

Fig. 3. Overview of software components within AquaUrsa's embedded hardware.

A. Drivers

Several driver components allow the DisCo framework to interface with actual hardware devices in the vehicle. All drivers are abstract, so that their operation appears the same to other components, regardless of their exact implementation, allowing easy migration to new hardware platforms. Currently implemented drivers include:

- A depth sensor driver that interfaces with the pressure transducer and informs other components of the measured depth.
- A heading and acceleration driver that communicates with the compass, accelerometer, and gyroscope, providing other components with tilt-compensated heading and acceleration information.
- A motor controller driver that accepts motor commands and generates the PWM and direction signals required by each of the thrusters.
- A sonar driver that receives the time-differences-of-arrival of the four sonar signals,

and provides the results to the high-level sonar localization components
- A frame grabber driver that captures camera stills and provides them to the image processing components.

The driver components are responsible for initializing a device, communicating with it via the appropriate protocol, and passing information between devices and higher-level software components. In addition, each driver supports a simulation mode used during testing and debugging. A special “log driver” allows one of AquaUrsa’s runs to be “replayed,” also for debugging purposes.

B. Vision

AquaUrsa’s Vision subsystem implements several different image processing algorithms that can be used to locate the various objects necessary to complete the vision tasks. The vision processing system locates the center and/or the angle of the current object and passes that information to the Navigation and Mission Planning components, which will determine the AUV’s actions based on this information. The utilized algorithms include:

- Hue-based colour analysis
- Various methods of extracting information from the object’s shape: edge detection, locating contours, Hough line analysis.
- A cascade classifier, using Haar-like features for object recognition

The implementation of the algorithms themselves is provided by OpenCV [2].

The Hue-based analysis consists of two main components. The simpler one looks for significant deltas between the hues of neighbouring regions. The other one involves normalized cross-correlation between the hue of the latest camera image and a template image, which has been manually provided to the algorithm.

The image processing component that deals with shape-related information, combines several algorithms, together with the known information about the target object’s properties. It first performs canny edge detection (after preliminary hue-based analysis has been done). Then, it attempts to locate the image contours and uses Hough line analysis to find lines in the image. After that it performs task-specific processing, using the expected configuration of lines and contours for the object that is currently being tracked.

The Haar features-based detection is based on the ViolaJones object detection framework [6] with additions by Lienhart [5]. This method is traditionally used for face detection but can be applied to detection of arbitrary objects, including the objects in the missions. It utilizes simple features, combined together using a cascade of boosted classifiers [6]. The types of features include edge, line and center-surround features (as described in the OpenCV manual [3]).

Different tasks use different combinations of these algorithms in order to perform the most suitable analysis for the particular task. In addition, for most tasks there are several alternative processing methods available, which attempts to address the frequently changing competition conditions.

C. Sonar

In order to determine the position of the sonar pinger relative to AquaUrsa, the time-difference-of-arrival (TDOA) of the four hydrophones is used, by performing a multilateration calculation. Given the four times of arrival, an analytical solution of the multilateration equations is calculated using the method developed by R. Bucher and D. Misra [4]. Once the relative position of the pinger has been calculated, the sonar component calculates the relative heading and updates the horizontal controller component with a new target heading, causing it to turn AquaUrsa towards the acoustic pinger.

All the software for the sonar FPGA board is written in VHDL.

In order to determine the position of the beacon relative to AquaUrsa and transmit the results to the main control board, the software are divided into four sub-phases:

- Preconditioning
- TDOA Calculation
- Beacon Positioning Calculation
- Slave mode SPI Communication

The preconditioning involves in-coming data detection, filtering, and amplification feedback control. Since the beacon we are detecting generates bursts of signals, the data detection unit only triggers the data collecting process while useful signals are captured by the hydrophones; meanwhile, because of the discrete-time nature of the collected data, a bandpass filter is needed to filter out all other aliases on the frequency spectrum outside of the range of 20KHz to30KHz; finally, the amplitude of the signals received by the hydrophones varies as AquaUrsa moves. Hence an FFT block is programmed to detect the signal strength and control the amplification index of the amplifier box, in order to maintain the data within a reasonable range.

The TDOA calculation is based on the mathematical concept of cross correlation [7]. As it is named, this method compares the correlation between each pair of signals and outputs the time differences. The Beacon Positioning Calculation adopts Nelder-Mead Simplex method, which is a numerical iteration method [8]. It takes the TDOA results as well as an initial guess as inputs and converges to a single 3D location. Finally, the positioning information is sent to the main control board via SPI upon inquiry.

D. Navigation

The software team developed a generic PID controller in order to be able make decisions about how to control AquaUrsa's actuators based on current mission requirements and sensor readings. The controller component itself is independent of the actual item being controlled, allowing it to control different items and making it easier to maintain. The higher level components can use the controllers by requesting that the target of the controller be changed as well as starting or stopping individual controllers and changing the gains and other parameters.

Heading and depth control are done by monitoring the current output from the digital compass and the depth sensor, and feeding them to the respective controller instances which determine the appropriate power for the thrusters.

When performing a vision oriented task, the vision processing component produces a location and/or relative orientation for the object being tracked and sends that information to the appropriate controller. The target of the position-based vision controllers is the middle of the frame and the heading-based vision controllers typically target being parallel to the object. AquaUrsa only moves forward when the actual position of the object is within a certain threshold (usually set to ±10% from the center of the frame) of the target and the rest of the time it corrects its orientation and position without moving forwards. This is done to make it easier for the controllers to achieve their goal and to reduce the chance of completely losing the object.

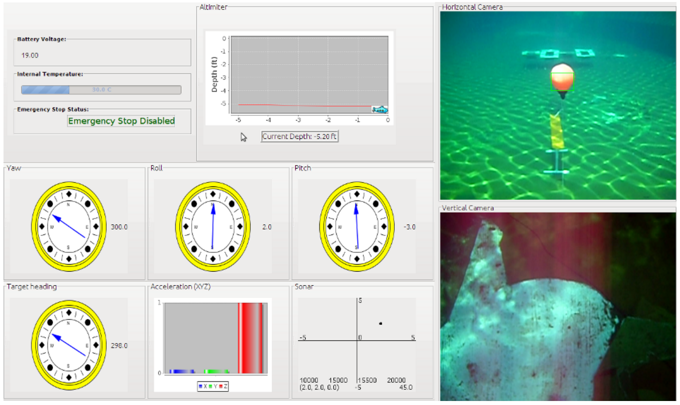
Battery Voltage: 19.00
Internal Temperature: 30.0 C
Emergency Stop Status: Emergency Stop Disabled
Current Depth: -5.20 ft

Fig. 4. Visualization of sensor data

Similarly, for the sonar mission, the Sonar component updates the target of the heading controller by taking into account both the current heading (from the digital compass) and the heading of the pinger relative to AquaUrsa, as calculated by the Sonar component.

E. Mission Planning

The Mission Planner component is responsible for running and supervising the missions AquaUrsa performs. Each mission, e.g. "pass through gate," "locate pinger," has a completion condition (which describes the criteria for success) and a time-out time (the maximum time to take on a mission before giving up). When either the completion condition or time-out time of a given mission is reached, the Field Commander terminates it and moves to the next mission.

Parameters for each mission are stored in XML files that are automatically reloaded upon being changed. This allows the parameters to be quickly updated during development, testing and competition.

F. Graphical Display / Remote Control

During testing, various sensor data can be visualized, including live video annotated with image processing information, sonar data annotated with pinger position and orientation information and data from the various other sensors, as shown in Figure 4. This can be performed in real-time while AquaUrsa is being tested, or with recorded data from a previous run.

In addition to visualizing important data at a glance, this interface can also act as a remote control. The operator can issue a target value for the depth controller component, and can also control AquaUrsa's yaw in one of two ways: by directly issuing a turning effort command, or by adjusting the target of the heading controller component, causing the vehicle to turn to face a specific direction.

V. COMMUNITY OUTREACH

ARVP has a mandated community outreach program in addition to its technical activities. ARVP members donate their time in an effort to educate the public about robotics and engineering. The primary audience of the outreach program is school-age children, who are encouraged to pursue careers in science, enginering and technology.

ARVP regularly makes appearances at public events hosted by the University of Alberta and its Faculty of Engineering, such as the Open House, Dean's Engineering Reception, and Faculty of Enginering CO_2 Car Races, with demonstrations and information about robotics.

Classroom visits and mentoring sessions are an especially effective way to connect with future engineers. In the 2013–2014 academic year, ARVP has conducted such diverse activities as classroom visits and demonstrations, soldering and microelectronics workshops, and interactive sessions using Lego MindStorms kits. These sessions provide an encouraging, up-close look at the opportunities available in the robotics field, and more importantly, are thoroughly entertaining to the participants!

VI. CONCLUSION

The latest AUV platform developed by ARVP allows for an extended set of competition tasks to be attempted. AquaUrsa will visit San Diego with vision, sonar, and marker dropping capabilities, a huge addition to the team's possible sources of competition points.

The new competition features have been integrated into redesigned, improved mechanical and electrical systems that will allow AquaUrsa's mission control software to reach the limits of its capability. In particular, the re-worked vision and sonar systems provide great opportunities for the team to increase its standing in the competition.

Given the hours of design, fabrication and testing that have been poured into AquaUrsa over the past year, ARVP is confident in representing western Canada with pride at RoboSub 17, and in having developed a solid foundation on which further improvements can be made for future competitions.

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In addition to the valued assistance of the U of A, ARVP is grateful for the assistance of its other external sponsors. Their generous donations of money, materials, deferred services, and discounted hardware are an important reason for the team's success this season.

ARVP's sponsors for the 2013–2014 season are, in alphabetical order:

- Abma Machine (services)
- Alberta Printed Circuits (services)
- Bruin Instruments
- Cetacean Research Technology
- MARL Technologies
- MacArtney Underwater Technology
- Shell Canada (via Shell Enhanced Learning Fund)
- Virgin Technologies Inc. (services)

ARVP could not exist without the outstanding external support the team receives from each of these organizations. Their support is hugely appreciated!

REFERENCES

[1] Efficiently detecting a frequency using a Goertzel filter. [Online.] Available: http://netwerkt.wordpress.com/2011/08/25/goertzel-filter/.

[2] OpenCV. [Online.] Available: http://opencv.willowgarage.com/.

[3] OpenCV object detection using Haar-like features. [Online.] Available: http://opencv.willowgarage.com/documentation/object_detection.html#haar-feature-based-cascade-classifier-for-object-detection.

[4] R. Bucher and D. Misra. A synthesizable VHDL model of the exact solution for three-dimensional hyperbolic positioning system. *VLSI Design*, 15(2):507–520, 2002.

[5] R. Lienhart and J. Maydt. An extended set of Haar-like features for rapid object detection. In *Image Processing. 2002. Proceedings. 2002 International Conference on*, volume 1, pages I–900 – I–903 vol.1, 2002.

[6] P. Viola and M. Jones. Rapid object detection using a boosted cascade of simple features. In *Computer Vision and Pattern Recognition, 2001. CVPR 2001. Proceedings of the 2001 IEEE Computer Society Conference on*, volume 1, pages I–511 – I–518 vol.1, 2001.

[7] F.Gustafsson et al. Positioning Using Time-difference Of Arrival Measurement. Linkoping University, Sweden, April 2003. Available: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=arnumber=1201741 [Accessed 27 June. 2014]

[8] J.Nelder et al. A Simplex Method for function Minimization. Computer Journal 7(4), Jan 1965,pp.308-313.