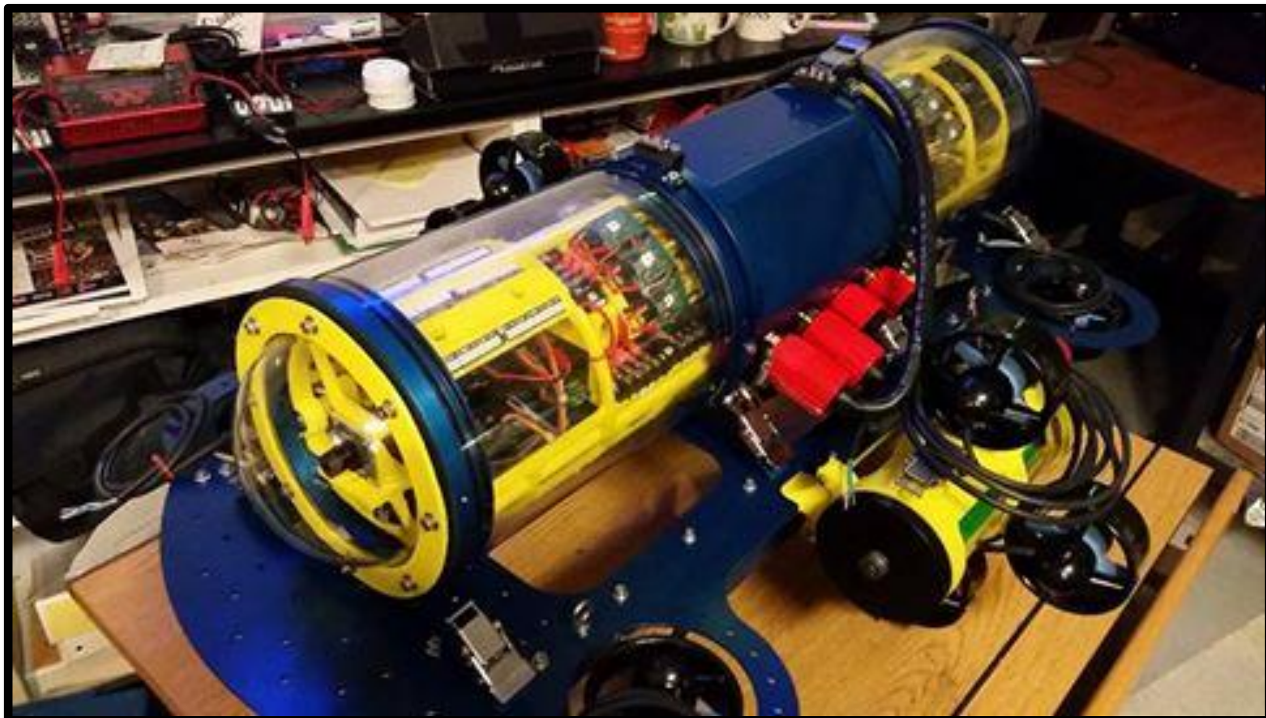
FALCON ROBOTICS AUV TEAM
PROJECT HABOOB 1.0



Abstract:

This year marks the 6th year that the Falcon Robotics team is competed in the AUVSI, Robosub competition. In our quest to design an AUV capable of winning the event it seems that we have delved into a two year AUV development project. As a result, our AUV, Haboob, is not complete and will be making appearance at the event for testing purpose. After watching and participating in Robosub for the length that we have we have decided to go all out and design and build an AUV that promises to be one of the best AUV's that Robosub has seen. We will have the ability to pinpoint our position in the water using a DVL and track it on our virtual map of the field. In addition to navigation, we will be able to triangulate the location of a pinger and surface in the correct octagon. Marker droppers and torpedoes will also be included as the AUVs compliment of capabilities. Of course we will have a robust vision system with a forward and down facing cameras. Mission specific task manipulation will be included using the eight pneumatic solenoids in the pneumatic module. Because of the complexity of our AUV and the less than robust affiliation with vendors in the industry it has become necessary that we take two years to complete this AUV.

Introduction

Team background

Located in central Phoenix, Arizona, Carl Hayden High School is an inner city school with many common inner city challenges. Some characteristics that further distinguish Hayden include, 98% of the student's population qualify for the federally assisted school lunch program, 97% are Hispanic, and an overwhelming majority are first generation immigrants. Many of these students are also the first in their family to graduate high school.

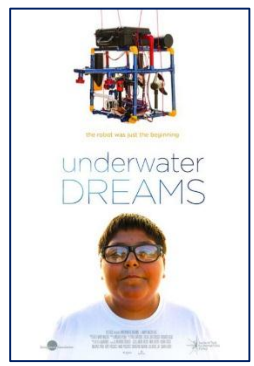
In 2001, Allen Cameron and Faridodin"Fredi" Lajvardi formed the Falcon Robotics team. The club came together initially to show students that science and technology could be interesting and fun but it rapidly evolved into something far more powerful. Now the team is a school within a school or a "robotics academy" of sorts. An average of 3 hours a day are spent by students and mentors designing and constructing robots to compete in various competitions year round. The competitive spirit, a sense of social responsibility, along with the natural aversion to embarrassment drives the learning experience. The program continues to thrive!

Team Outreach

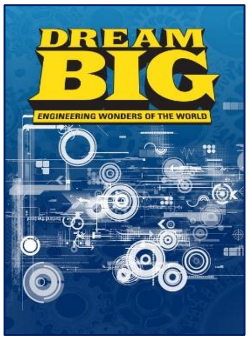
The Falcon Robotics team has many outreach activities. From holding Lego robotics competitions for grade schoolers to science and technology fairs for the public, the team has been very instrumental in

affecting STEM education in Arizona. There are three Robosub teams here because of our encouragement for them to compete in Robosub. Arizona State University, University of Arizona and Women in Engineering Program, Texas A&M University. We have been trying to engage Northern Arizona and Grand Canyon University to participate as well, but it may take another year.

As far as the influence we have in the area of STEM education and promoting ROV and AUVs in education, it is difficult for anyone else to match. The team has had many documentaries starting back in 2005 with the breakout story of how the team beat MIT in the MATE National ROV Championships, covered by ABC Nightline. The team then had its next national exposure in 2010 on CNN with Soledad Obrien's In America Series with a documentary called Don't Fail Me. A full fledged documentary film was made in 2014 by 50 Eggs.com called Underwater DREAMS.



This film was even screened in the white House and President Obama recorded the introduction for it! Early in 2015 the Hollywood version of the team's victory in the MATE competition came to theaters across America in a film Called Spare Parts, starring George Lopez, Jamie Lee Curtis and Marissa Tomei. If all this doesn't seem pretty impressive, MacGillivary Freeman Films is currently filming a documentary called



Dream Big which will feature several stories of people defying the odd to do incredible things in the STEM fields of which our story will be one. This film will out Feb 2017.

The article in Wired Magazine that came out in 2005 started the whole ball rolling, as far as the national attention goes. The author, Joshua Davis, also wrote a book called Spare Parts which delves into the backstories of the people involved and where they are today. His story in Wired Magazine has been adopted by three textbooks for English language Learners.

The team has also been very accomplished in the world of FIRST Robotics. FIRST is an acronym for For Inspiration and Recognition of Science and Technology, a worldwide high school robotics program. The falcon Robotics team has been inducted into the Hall of Fame which the highest honor a team can get in FIRST.

There are many youngsters out there that have been exposed to one or more of the above mentioned forms of media exposure and they have been motivated or inspired to go into STEM. We have a big impact!

Design Rationale

The AUV has been designed with a central spine for all the external connections. This central spine approach was used so that a complete redesign is not needed every time a modification is made. In other words there are two polycarbonate hulls that fit on either end of the main aluminum hull. The length of either hull can be altered to accommodate the new modification without needing to rebuild the whole AUV. Each polycarbonate hull is capped by an aluminum end cap. The frame on which the hull is attached to and where the thrusters are connected can be easily modified to accommodate a new hull length. The frame is a three piece water jet construction that is very easy to manufacture.

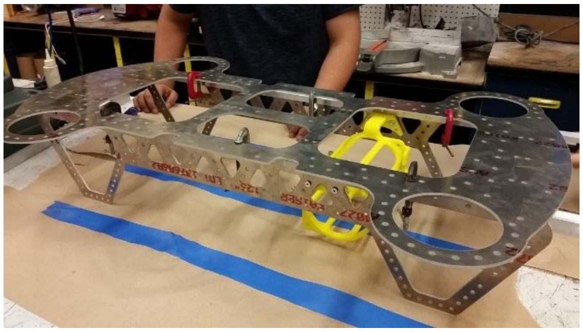
The thruster configuration is setup to provide movement in any direction and the AUV can pitch and yaw to give it that extra movement capability if needed. The thrusters are Ble ROV thrusters that provide 5 lbs of thrust each and we have twelve on our AUV. For forward travel we have 6 thrusters to prove 30 lbs of thrust and to ensure that the AUV is plenty fast enough to cover the field without wasting time.

Many of the parts of this AUV are 3-D printed PLA. This allows for lightweight production of component mounts and lattices that otherwise would be impossible to make. The team is gaining much experience at using PLA for making parts that are lightweight and strong enough to get the job done.

To get the full range of motion and the ability to pitch and roll as well as be fast when traveling forward, the team decided on 12 Blue Robotics thrusters. There are 4 thrusters for a vertical thrust of 20 lbs and 6 horizontal thrusters for forward thrust of 30 lbs movement as well as 2 thrusters mounted for lateral movement with a thrust of 10 lbs.

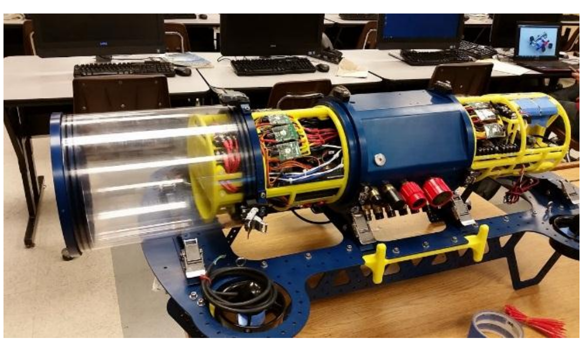
AUV Construction

The AUV frame consists of three sheets of aluminum, one is the main plate where the main AUV hull is attached to and the two other pieced form the legs that hold the AUV upright on land.



The main hull is made of several sections to allow for future modifications and ease of maintenance. The center section of the main hull is comprised of a ½" aluminum tube that has been faced off so that industry standard what tight connectors can be mounted. It acts much like a spine for all the thrusters and external sensors and instruments. On each end of the main hull

are removable polycarbonate tubing bordered by an aluminum ring on one side and a thermal exchange endcap on one tube and a acrylic done on the other tube. The



aluminum rings allow for a water tight seal to main the hull. The tubes are secured with spring loaded latches.

All the electronics are mounted on 3-D printed PLA that are secured to the main hull on three aluminum rods. It is done this way so that it allows for ease of maintenance and or replacement in the future.

The battery housings consist of polycarbonate tubing with ABS endcaps. They come equipped with a pressure relief valve and an electrical Subconn connection.

The same type of setup is used for the pneumatics module and the DVL module. The DVL is slightly different in that it has an aluminum fixture on one end so that it could accommodate the DVL head that needs to be in a 90% differential in relationship to the polycarbonate tube that houses the electronics.

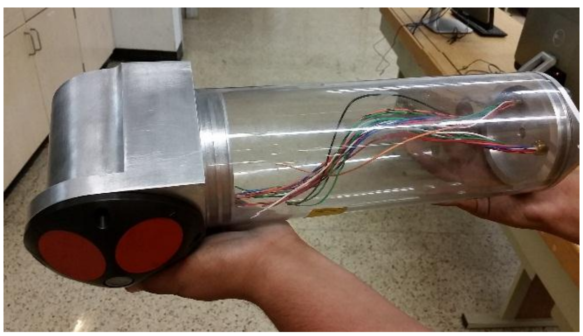
Many of the devices that are external of the main hull use 3-D printed PLA to mount or secure them to the frame of the AUV.

Electrical

There are two separate power sources in this year's AUV. For propulsion there two 11.1 Volt, 10 amp/hr LiPo batteries hooked up in parallel. For the CPU and navigation there is a 14.1 V 10mp/hr LiPo that runs through an ATX power supply. The battery hulls are transparent so that we can check for leaks and to see that digital battery status indicators.

Navigation

Teledyne Explorer DVL: The DVL is an ultrasonic device with 4 beams. The DVL allows the sensing of depth using time of flight (TOF) of the ping as well as X-Y translation to ~ cm level precision using Doppler shift as well as other signal processing techniques. . The DVL cannot however form a navigation position solution by itself as it cannot sense heading changes. The DVL will be housed in a separate hull to make removal from the AUV quick and easy removal as we will be sharing the DVL with the University of Arizona team.



KVH DSP-1750 single axis Fiber Optic Gyro (FOG) The DSP-1750 FOG provides an ultra stable angle sensor that is capable keeping drift below 0.1 deg/hr (one sigma) when properly calibrated under optimal conditions. The gyro has enough stability to accurately measure the rotation rate of the earth and this is zeroed out as part of the initialization process for the sensor.

The FOG rate drift is affected by temperature changes so we will let it warm up and the hull temperature to stabilize before starting the mission. The gyro works by sending laser light in opposite directions in a spool of optical fiber and as the spool is rotated with the AUV, an interferometer in the FOG counts the rate of nulls and estimates the rate of angle change. The angle rate is integrated numerically 1000x per second to form the (heading) angle estimate for the navigations system. The FOG must be kept level or it will have an angular rate error proportional to the cosine of the tilt angle away from the level position.

Vision

Vision system: This is comprised of several components.

1. The vision processor (the “main computer”),
2. Two HD USB board camera. (one forward and one down)
3. And the viewing window. (Two inch dome)

The viewing window is mentioned because is has a significant effect on the field of view of the camera. We elected to use a dome with a depth of 2” and a diameter of 6” to minimize the reduction of FOV underwater that results from using a flat window. This shallow dome has less optical power (less FOV) than a 6” diameter hemisphere.

Software architecture

There are four separate programs that run our robot. The Teensy microprocessor handles all of the inertial control loops, maintaining our robot’s attitude and position in the pool by directly reading from the robot's inertial sensors and feeding the motor escs the control loop output. The teensy process communicates telemetry information and receives set points from the main program.

The main program is written in Java and runs on the main computer. It is what handles mission planning, managing the various settings, logging data, and acts as the communications hub. The mission planner reads from a json file that describes the tasks and the task order for the mission. The settings system saves in a similar fashion, reading and writing to a json file. When the program boots, all the settings are read out of the json file into a map that is stored by the program. The settings are communicated to the other programs in a system similar to that of TCP, where the settings are indexed and the teensy occasionally informs the main program of the highest index where all settings below that index are up to date. The main program, upon receiving that information, will send the next 10 settings from the index received. This way the teensy won't be flooded with all the settings immediately after boot.

The vision processing is done by an entirely separate program, running on the same computer, written in C++. It receives filter commands and values from the main computer, sending back coordinates and such information. Our vision system can be configured by using different "blocks". Each block represents one process, for example it could be a read from camera block, a filter block, or a display image block. Each block is it's own separate thread, and it passes frames along by reference, using a pointer buffer on both the input and the output to organize it's todo list.

The Operator Interface, written in java, is run on the surface by a laptop. Multiple instances of the OI can be run at once from multiple laptops, allowing for easier viewing. The OI is also designed so that the AUV can be run without it, so that our runs can qualify for points. The OI can manage a variety of tasks, each task is designed into an "App". The OI is divided into panels, and each app can occupy any given panel. The apps can be dragged between different panels, two apps can even occupy the same panel, by using a tabbed system. Each app can have settings, configurable by the operator by double clicking on the app's tab. Currently, the list of apps that the operator has access to are as follows:

- OIConsoleApp, for displaying general debug messages from the robot
- CommSettingsApp, allowing the operator access to some of the communications settings.
- OIVideoApp, which displays the video feeds from the robot cameras.
- GamepadApp, for reading from and sending gamepad values to the robot.
- TelemetryGrapherApp, displays selected telemetry values to a graph on the OI.
- RawTelemetryApp, displays all telemetry values to a text window on the OI

Processors

The main computer this year is an Intel i7 @ 4GHz on an asus micro ITX motherboard, with 8 GB RAM. It uses a 240 GB SSD for the important systems and a 1TB HDD for general storage. Key tasks for this processor are data logging, vision processing and task sequencing.

I/O processor: We use two Teensy 3.1 microprocessors as our GPIO devices, connected to the Main PC over USB. They are both mounted on a custom PCB to simplify cable management. The PCB has connectors for all of our devices, like the DVL, the motor controllers, the Gyro, etc. the bidirectional interfaces are mostly asynchronous serial data (RS232 and TTL). Also, there will be standard servo type PWM outputs for the 10 thrusters.

The INS (Inertial Navigation System) processor: Will be one of the two Teensy 3.1 devices. The INS processor reads the raw information from the FOG, DVL and other sensors and forms a navigation solution of the X-Y position, attitude and depth of the AUV in the pool. This navigation solution is used by the Task sequencing processor in order to trigger AUV actions to perform the tasks.

Future plans

It is difficult writing this report when the AUV is not complete. We are mainly submitting this one to have something in. But, next year we hope to be fully fleshed out to be able to be a serious contender and that time this report should be something we will really be proud of. As far as the AUV we hope to have an AUV that is fully capable of doing all the mission tasks and hopefully put us in contention for the win next year at Robosub!

References:

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