STRIDER(Semi-autonomous Tracking Robot with Instrumentation for Data-acquisition and Environmental Research)-Pitfalls and Successes of a Vertically Integrated Experiential Learning Project spanning Multiple Years

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Abstract:

The Semi-autonomous Tracking Robot with Instrumentation for Data-acquisition and Environmental Research (STRIDER) is conceptualized as a wireless controlled aquatic robot with the capability of taking water samples as well as in-situ water quality data. STRIDER can be operated into either salt or freshwater to provide water quality data at the surface as well as at specified depths over a representative area over a chosen water body. The STRIDER team consists of a small group of engineering majors as well as students from other fields collaborating to meet the requirements set by scientists at the Environmental Monitoring and Food Safety Laboratory (EMFSL) of United States Department of Agriculture (USDA); under the advice of a few faculty members at the University of Maryland Eastern Shore (UMES). STRIDER currently has the capability of providing critical geo-located measurements; pH, Oxidation Reduction Potential (ORP), and Dissolved Oxygen (DO) values at the surface and other specified depths. This data can be interpolated over the surface, as well as across the depth to provide a three-dimensional representation of the variation of water quality parameters of a chosen water body. This project has allowed for the development of multidisciplinary research and experiential learning framework to engage students at UMES within and outside the classroom. Many different components of engineering design, environmental sciences, and other related fields are integral to this project. An overview of the design challenges and accomplishments of the team are provided in this work.

Introduction:

STRIDER project has been ongoing at UMES in collaboration with USDA EMFS Laboratory scientists and staff since 2014 and has provided a platform for experiential learning, research, and engineering design with the overarching goal of semi-autonomous sampling and water quality measurements in relevant water bodies [1, 2]. The design efforts have undergone several iterations for improved performance and capabilities. As students involved and leading the project have moved on and graduated new student groups have filled in under the advice of involved UMES faculty and USDA scientists. The newest version of STRIDER that is under development version utilizes a commercial-grade water quality sampling unit called an ISCO 6712 Full-size Portable Sampler. This paper outlines and illustrates the recent efforts with the STRIDER project primarily devoted to improving the existing platform [3,4] under the leadership of the primary author.

Figure 1: Field Trial with STRIDER

Objectives:

Objectives for STRIDER's mission are to provide a cost-effective method for semi-autonomous water quality sampling and data collection on an in-situ and ex-situ basis. Utilizing STRIDER to obtain geo-located measurements of Dissolved Oxygen(D.O.), Oxidation Reduction Potential(O.R.P.), and pH measurements at specified depths can be mapped and interpolated for three-dimensional analysis of the water body. STRIDER is also to be eventually delivered to the USDA researchers and staff to do a bacterial analysis of the water samples collected from the water bodies using the system.

Materials:

STRIDER’s pontoons are constructed of sealed foam and positioned according to the distribution of weight on the platform. The platform is affixed to three metal square tube beams of aluminum welded to three cross braces. The platform base is the foundation that is attached to the tri-toons.

Figure 2: Student Team Moving STRIDER

Figure 3: Electronics box containing Central processing unit and electronic speed controllers

The winch is comprised of two sets of triangle frames and a central shaft that allows a drum to be rolled up and down. Cables for sensors and tubes for the water quality run through the center of the shaft such that the cables do not experience extreme loading when turning the winch or rotation at the joint. Water samples are pumped using a peristaltic pump mounted on the starboard side behind the winch. The turntable is comprised of a stepper motor and gearbox that connects to a circular board with mounts for bottles concentrically. Through the center is the output of the peristaltic pump which deposits water samples into rotating bottles. At the stern of the boat, there is a mount for a 12v glass-mat battery and the electronics box. On the port and starboard side of the stern are two 12v high torque dc motors which power the paddlewheels made of aluminum [see Figures 1 and 2].

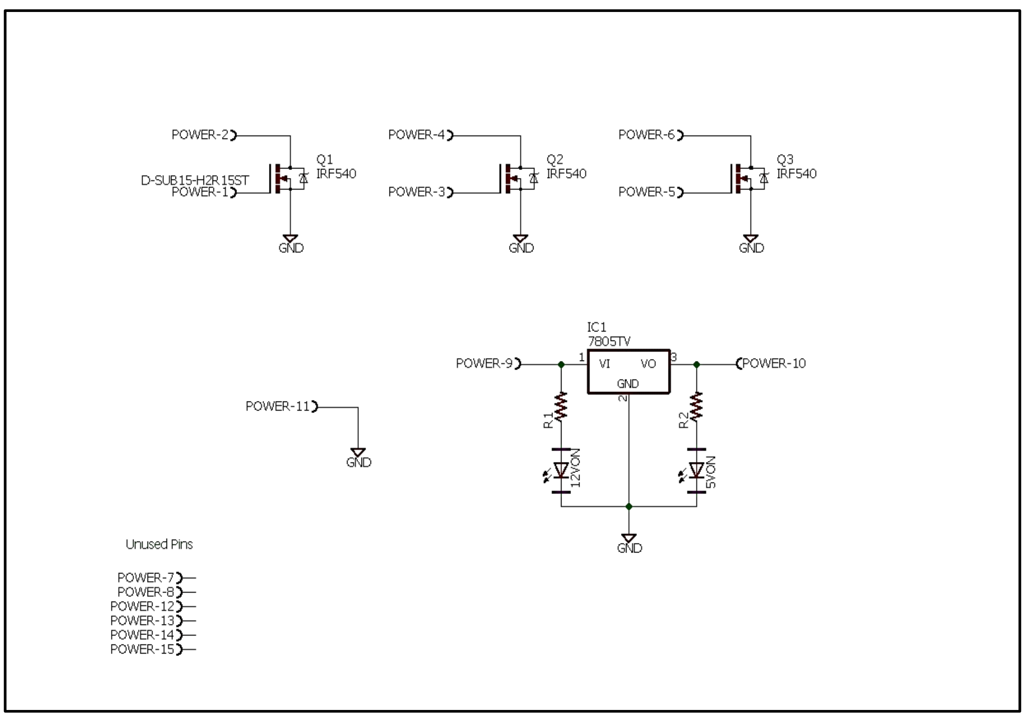

Figure 4: Designed wire diagram for power distribution system.

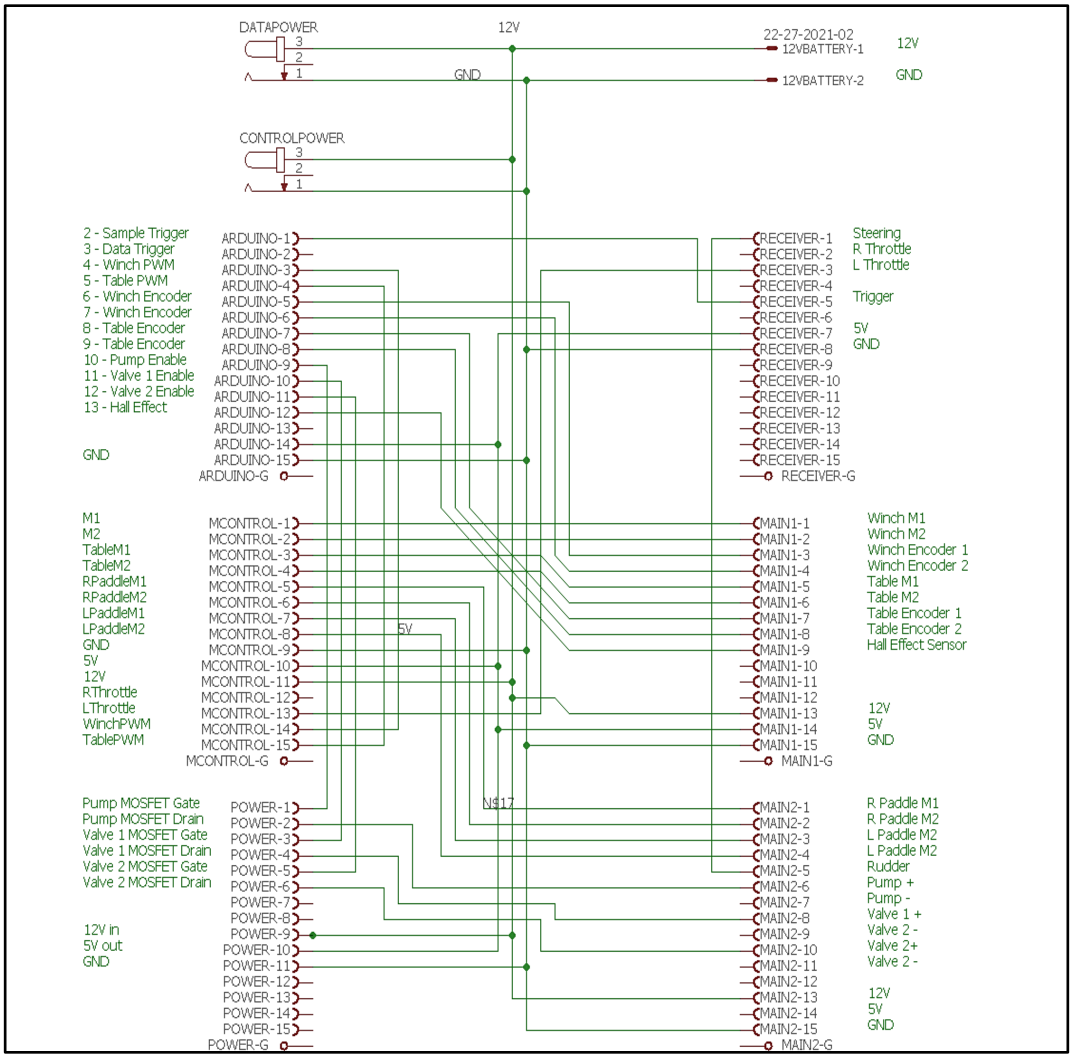

Figure 5: Designed wire diagram for STRIDER's wire harness.

The speed controller and the electric set up and the wiring diagrams for the STRIDER set up is shown in Figures [3-5].

STRIDER's electronic box has a waterproof quick connect at the left-hand side of the electronics box shown in Figure [4]. The wiring for this quick connect is shown in Figure [6]. This is done to ensure that when the box is closed; under no uncertain circumstances will the electronics short due to water. There is also a fuse located in series with the power distribution system that will stop all power if current exceeds the fuse limit. This power distribution system is shown in Figure[5]. The power distribution system splits the signal coming from the battery into various reference voltage(5v), 12v and 6v lines which are routed to busses and used throughout in the various processors, speed controllers, fans, and other components.

Methods:

The efforts undertaken by the new student team to improve the STRIDER platform reported earlier [3] utilizes a tri-toon boat platform for added stability and buoyancy. A turntable with a fixed dispenser is used with 15 different possible water samples (see Figure 6). It may be noted the version reported earlier could carry only 7 bottles [3]. The platform can collect water samples from five locations at three different depths. This data can be interpolated for three-dimensional analysis of the water quality of the body of water in which the system is deployed. STRIDER utilizes a programmable logic device (PLD) with a bootloader called an Arduino Mega. This PLD has been modified through the use of platform IO to run an Arduino/Object-Oriented C variant which has been deemed Object-Oriented Arduino code compiled outside of the Arduino in a virtual bootloader in Visual Studio Code. This code is then injected into the Arduino on the armature that matches the specification of the virtual bootloader. The Mega can control both the navigational aspect of the boat as well as the scientific logging and acquisition through the use of the DO, ORP, and pH sensors. These in-situ measurements provide primary data sources that can be used quickly and efficiently for analysis in conjunction with the ex-situ samples that will be processed by the USDA EMFSL staff.

Figure 6: 15 Bottle turntable dispensary system.

Results:

A portion of the STRIDER code developed by the team is shown in Figure 7. The code activates the hardware and the sensor system for the sampling set up with the 15 bottles and ensures that for every individual sample the suction snout is directly over the respective bottles so that peristaltic pump when activated fills the appropriate bottle for a specified length of time. A stepper motor is used with a gearing arrangement similar to a Lazy-Susan for appropriately indexing the bottles during the field operations. The boat can be operated both with remote control and autonomously to move it to 5 GPS locations where it takes samples from 3 different depths at each location. At the time of writing this paper the field trials for sample collections have been successfully accomplished for the improved platform. Modifications are underway to write the GPS locations for each of the 5 sampling locations covered for a single run and the DO, pH, and ORP values obtained from sensors deployed using the winch system at the various depths on an SD card. The data from the SD card will be processed and mapped using software such as GPS Visualizer and/or ESRI- ArcMap.

```
}
void loop() {
    lMotor.writeMicroseconds(Trigger.Channel3(MicroSeconds));
    rMotor.writeMicroseconds(Trigger.Channel4(MicroSeconds));


    //Move the table to its initial home position for precision of table
    while (digitalRead(tableCheck) == HIGH)
            {

                Table.step(25);
                delay(500);
            }
    // This if statement is to have the trigger start the table sequence
    if(Trigger.Channel1(Bool) == 1 && tableIndex <= tablePositions){
        //This loop is to make the winch and table work but only when the table is at home position
        while((winchIndex <= winchPositions) && (digitalRead(tableCheck) == LOW)){

            lMotor.writeMicroseconds(Trigger.Channel3(MicroSeconds));
            rMotor.writeMicroseconds(Trigger.Channel4(MicroSeconds));
            tableIndex++;
            winchIndex++;
            Winch.step(winchIndex*1500);
            pumpAssembly(purgeTime);


            delay(500);
            //This code is to step the table to the appropriate distances in the tableCal matrix
            Table.step(-1*tableCal[tableIndex]);
            delay(500);
            pumpAssembly(sampleTime);
            /*This algorithm fixes the issue with poor signal quality from the moveTo function
              It also fixes the issue of the drift the table preforms when moving the same steps back
              This code is imperative to the table to not miss the home position */
            Table.step(290*(tableIndex)-70);

            //This loop is to return and check if the table is at home position
            while (digitalRead(tableCheck) == HIGH)
            {
```

Figure 7: Portion of the STRIDER code for appropriate indexing of the sampling bottles

Work in Progress and Future Work:

STRIDER can be further optimized by adding additional components as well as upgrades to the current infrastructure. GPS logging in conjunction with a water quality data package that includes pH, dissolved oxygen, and oxidation-reduction potential sensors will allow for the interpolation of data in a three-dimensional array for the water body. Re-manufacturing the paddlewheels to steel instead of aluminum will provide for a robust power delivery system. Implementing a flight controller to open processing power will allow for more computing while allowing for STRIDER to become fully autonomous if necessary.

In the second version of STRIDER [See Figure 8], the body consists of a single green commercially available kayak modified with an aluminum superstructure to mount the water sampler, thruster, and electronics. Aluminum outriggers are attached for stability with floats that are mounted to the superstructure. The ISCO water sampler goes into the drum-shaped mount which provides a secure location for it to rest near the center of gravity of the boat. The thruster is mounted at the stern of the boat by an aluminum mount with a tube pulleyed to a servo mounted at the stern of the boat also. This provides pivotal steering for the Blue Robotics T100 Thruster at the bottom of the aluminum tube. A 12v lead-acid battery is mounted behind the ISCO. The electronics box is mounted behind the battery which houses the main processing unit and flight controller

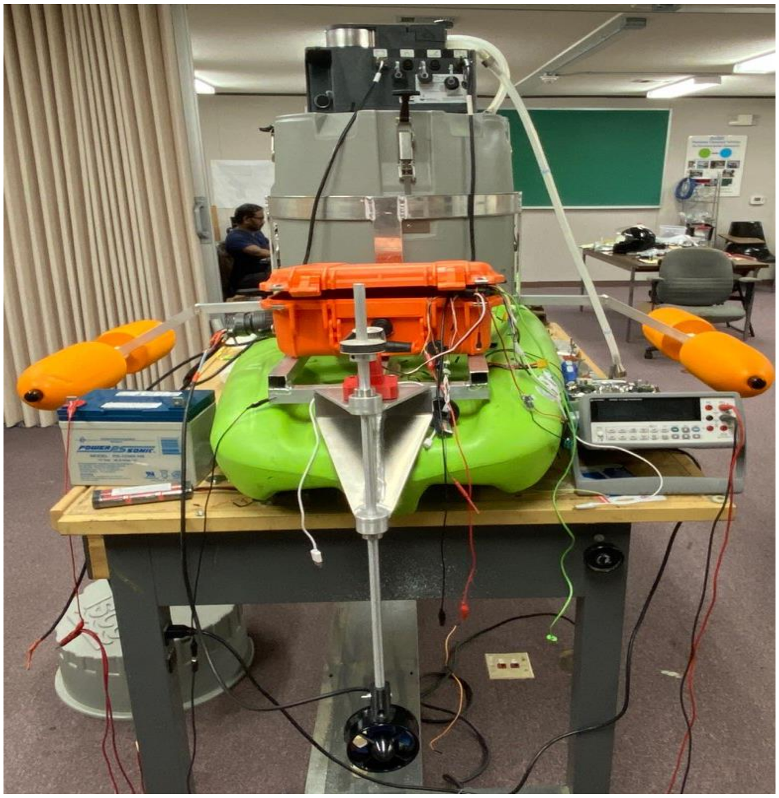

Figure 8: Work in progress with new STRIDER

Trials and tribulations recognized from the first STRIDER implementation have been addressed and attempts have been made to remediate the issues in the second version through the implementation of commercialized systems integrated with the platform. Student teams could not get together during the winter break on campus but improvements were achieved in the early part of the ongoing spring semester by the new student team. In early March the team successfully ran a navigation test with the new STRIDER. Figure 9 are photographs taken during the successful navigation trial. The team intended to do a data collection run with both the old and new STRIDER platforms in March-April time frame, however, all project efforts have been put on hold due to COVID 19 related restrictions and social distancing mandates on campus for the time being.

Figure 9: Navigation field Test of New Strider with ISCO Sampler

Acknowledgment:

The primary author and the student members acknowledge the support from USDA Beltsville EMFS Laboratory, Maryland Space Grant, and the faculty/staff advisors at UMES.

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