Robotic Ocean Instrumentation Design Project: Sea Glider

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***Abstract* — This paper discusses the motivation and design of the constructed glider. Design requirements included the incorporation of at least one actuator, one science sensor, one navigation sensor, and data logging capability. The sea glider successfully accommodates these requirements and with slight modifications, the developed glider could provide a low-cost glider capable of real-world scientific field sampling.**

***Keywords* — AUV, glider, MBED, sensors**

I. Motivation

On the most basic level, AUVs represent a marvelously efficient and effective means of collecting data in the ocean. They largely negate the need to send humans into the deep ocean by acting as platforms for cameras and sensors. In addition to being much safer, this also reduces the need for diving equipment, which can be quite costly [1].

Numerous aspects make gliders a desirable archetype within the AUV family. They do not have propellers, which means that not only is the risk of fouling on submerged lines greatly reduced but also that no corrections need to be made for “walking,” the process by which a rotating propeller causes its vehicle to steer to the side. Also, the lift force which propels them forward is generated passively rather than actively, and so they are extremely quiet while gliding and extremely efficient when there is a large range of depth available for them to glide through. The drawback of this passive propulsion system is that gliders are quite slow, typically moving at around 0.5 of a knot [2].

A kit can be purchased online which can turn a 1-liter water bottle into a gliding AUV, which is powered by a single 9V battery and run from an Arduino microcontroller [3]. The original intent was to adapt this glider to run from an MBED microcontroller and then integrate various sensory systems into it; however, the size of the water-bottle was prohibitively small. The goal of this project was to not only reorganize the software to run off of an MBED microcontroller rather than an Arduino, but also to reorganize the hardware of the glider into a larger housing that would allow sensors to be more comfortably added to the robot.

II. System Design

The first step was choosing a housing that would be large enough to host the breadboard, MBED, buoyancy engine, battery, and ballast as necessary. The replacement housing was the 3-inch diameter clear housing from Blue Robotics cut to a length of 1.5 feet. This was large enough to accommodate the glider’s internal components while remaining just small enough to be powered by the diminutively sized buoyancy engine. The glider’s internal components were secured by two rods running the whole length of the housing. Ballast was secured underneath the rods and was adjustable so that the glider could be trimmed properly.

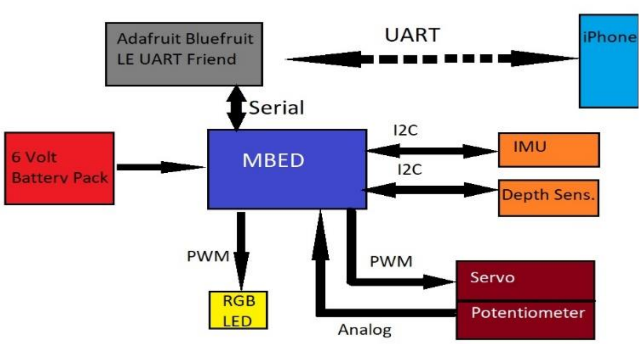
To accommodate the larger housing and thicker wings and rudder, a new nose cone, wing yoke, and rudder yoke had to be designed; SolidWorks was used to this effect. Since the servo motor was also being replaced, a new mount had to be designed to attach the servo to the buoyancy engine as well. Some components had been fabricated prior to the project’s adoption, but these were mostly sized to the smaller water bottle housing. Both the wing yoke and the rudder yoke were bound to the housing with zip ties, which provided a secure but easily removable mode of attachment. The nose cone was not part of the original smaller bottle glider design, and was used as additional housing for ballast and potential mounting area for additional payloads. The nose cones were sized to fit the diameter of the housing. Smaller holes were designed to reach the securing screws to make assembly easier. Additional holes were added to allow air and water to drain and fill the nose cone.

The ballast engine was formed by a large syringe driven by a servo motor, which was controlled by the MBED. The servo motor drove a lead screw which pushed a plunger in and out of the syringe. The syringe’s plunger was modified with a 3d printed part and ballast so that the oscillation of the plunger varies the center of gravity and buoyancy of the glider. Varying the center of gravity is important to a glider because this change contributes to the pitch of the vehicle allowing for forward motion. An RGB LED was used to indicate engine state: rising, paused, or diving.

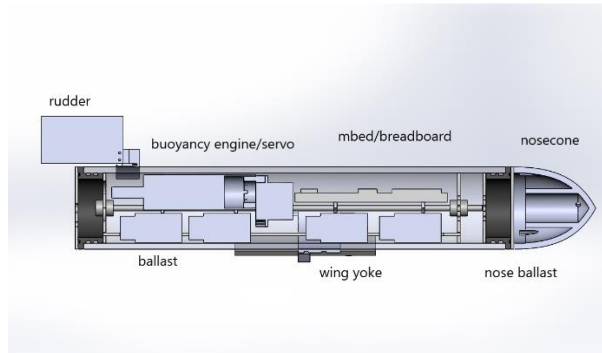
The motion of the plunger was bound on one end by a limit switch and the other by counting how many turns the plunger was along the screw; however, for various reasons these limits were sometimes over-driven, which caused damage to the buoyancy engine on multiple occasions. The limit switch was located towards the forward end of the buoyancy engine and bounded how much volume could be sucked in on a dive cycle. It took the form of a physical, aft-facing button which was depressed when the plunger was driven into it. Turns on the screw were counted in the engine's code using a potentiometer rigged inside the servo motor. The potentiometer output a value between 0 and 1 and was read at intervals of 0.03 seconds by the MBED. When one reading was greater than the previous reading by 0.5 or more, the potentiometer had rolled over and the turn counter was increased. If a reading was less than the previous reading by 0.5 or more, the potentiometer had rolled over in the other direction and the turn counter was increased. The plunger could safely travel 19 turns down the lead screw.

Fig. 1. The assembled glider mid-mission rising while set in the pause time mode.

An Adafruit Bluefruit BLE board was added to provide a serial connection allowing mobile devices to network with the MBED. This system was used to send updates to the mobile platform upon startup and initialization of the SD card reader, IMU and buoyancy engine. This connection was also used to transmit collected data while on the surface. The system was designed to be capable of collecting data - pitch, roll, yaw, engine position, and acceleration - based on ticker functions at preset intervals. The board also provided the capability of interacting with the MBED through a serial terminal on the mobile platform. This terminal is capable of setting the engine pause time - the time in which the glider would rise or dive - without recompiling code onto the MBED. Similarly, this board would also allow the mode of the glider to be changed from gliding based on a pause time to gliding using a hunt-and-seek algorithm with a depth sensor.



The glider was designed to accommodate a depth sensor to incorporate a feedback control loop. This was not achieved because the depth sensor was incapable of interfacing with the MBED. This hunt-and-seek mode would function with three parameters: a depth goal to which the glider would seek, a distance sensitivity in which the glider would seek the depth goal, and a mission duration in which upon completion the glider would execute a rise command and return to the surface.



III. Results

In the conducted trails only system time and pitch were logged to demonstrate the functionality of the glider.

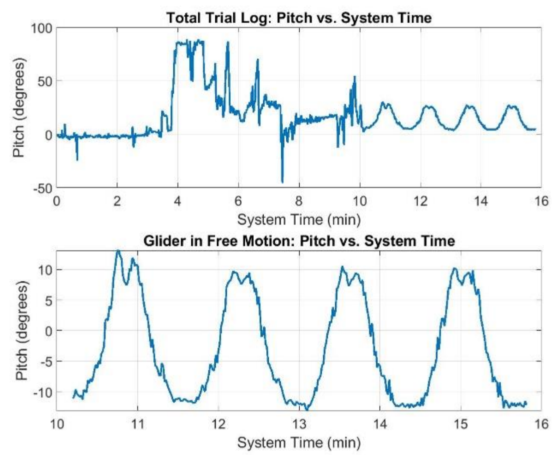


Fig. 2. The collected pitch data of a single system power cycle plotted against the system time.

The top plot displays the logged pitch from the entire trial while the lower displays the recorded pitch while the glider was in free motion. In sequence, the above plot shows the glider tray being powered on, a few engine cycles being completed outside of the housing, the tray being loaded into the housing followed by a few more engine cycles, the trim of the system being adjusted using the external magnetic fine ballasts, and then the glider solely acting under the buoyancy engine (repeatable oscillatory pitch plot). Fine adjustments to the trim were necessary as the 3d printed parts were not impermeable and slowly became saturated with water. This adjustment of the external magnetic ballast did affect the calibration of the IMU and for this reason, post trimming, the level system logged a pitch of about 14 degrees.

The below plot shows the glider being released at the surface while in the pause stage after a dive engine cycle. This is known because the system has a max negative pitch. The engine then enters a rising cycle in which the pitch increases until the engine is paused again and a constant pitch is desired. When the glider broke the free surface, the system bobbed and then entered a dive cycle in which the pitch decreased. During the pause after a dive, a steady pitch is maintained as the glider does not encounter any changes in external loading. This complete cycle is then repeated as the glider continued forward.

IV. Discussion and Recommendation

The sea glider performed all of the tasks that it was designed to do. While the depth sensor was not functional at the time, this is believed to be an issue with the sensor itself and not the program designed to run the depth sensor. Finding the correct buoyancy for the sea glider was crucial to the functional success of the design. This was accomplished by adjusting ballast weights and wings along the length of the hull, which required many trials to achieve an even pitch and neutral buoyancy, where the glider would maintain a desirable position to begin a dive cycle.

A main issue with the current design is the relatively small size of the buoyancy engine compared with the total size and mass of the sea glider. While the current syringe displaces enough water for the change in buoyancy to initiate rises and dives, the initiation of these cycles is very slow and at times does not create enough force to propel the sea glider forward in the water. Additionally, the servo motor used to change the buoyancy motor’s position has a slow rpm. Improvements on these fronts would ultimately lead to a more dynamic and responsive sea glider system.

V. Future Work

Plans for the system include addressing some of the discussed issues. A printed circuit or protoboard could replace the breadboard, thereby eliminating loose connections and providing room for a larger engine or additional payloads. Further development of the Bluetooth serial connection would lead to additional commands being sent and less code needing to be recompiled. The 3d printed servo mount and plunger could be redesigned to extend the range of the engine plunger. This would increase the changes in buoyancy and the center of gravity, making the system less sensitive to minor changes in trim. The next step critical to making this system field-ready would be to actuate the rudder on a feedback loop in order to adjust the heading of the glider. This could be accomplished with a stern-mounted waterproof servo. Additionally, the system would need better position awareness and the capability to transmit data over long ranges for recovery.

Currently, the system works and provides a proof of concept of the idea of a small inexpensive glider capable of collecting usable scientific data. With a few changes, the glider could be ready for an open water trial.

References

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