MAS 02 A Communications Framework for the Cost-effective Operation of Slocum Gliders in Coastal Regions

MAS 02.1 People

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MAS 02.2 Overview

Slocum gliders are a type of slow-moving Autonomous Underwater Vehicle platform to collect scientific data. These vehicles use buoyancy and gravity to glide through the water instead of relying on conventional propulsion techniques like propellers – a feature which gives these vehicles prolonged mission times of 2-5 weeks as compared to tens of hours in conventional AUVs.

Gliders can yield valuable data to oceanographers and scientists by allowing them to look under the surface (something which remote-sensing alone cannot accomplish). This data is essential to studying not only the physics and biology and can be assimilated in prediction models such as JPL’s ROMS model. Even though the gliders are very efficient in their use of power, the nominal cost of operations of a glider’s communications is typically around $180 per day since it usually relies on an Iridium satellite phone to send back data at each surfacing.

We need an alternative and more cost-effective mode of data collection than exclusively using satellite links. Starting in Fall 2008, we have designed, developed, deployed and tested several stages of a communications framework, which will enable us to get data back from gliders (and probably other data-collection platforms such as boats, and buoys), in a cost-effective and quick manner. This infrastructure requires minor hardware modifications to the glider, but coupled with software we developed, will allow gliders to relay data back to a central data-server via networked base-stations, which are strategically located in the Southern California Bight region. We are still in the process of testing and developing this network.

MAS 02.3 Approach and System Description

The glider is a specialized robot driven by buoyancy, which can fly in the ocean for extended periods of time, as compared to other AUV’s operation times, at the expense of speed and maneuverability. Power consumption minimization, is an aspect which glider designers have devoted significant efforts to. The glider’s navigation and communications are handled by a low-power micro-controller called the Persistor. This computer is capable of performing the regular navigational tasks for the glider and runs a modified version of PicoDOS called GliderDOS which contains glider-specific software.

Fig. 1 shows a typical scenario with three gliders in operation where Glider 1 and Glider 2 are connected to Base Station A and Base Station C respectively. Glider 3 is out of range with any of the base-stations and has to connect to the Glider Control Server via Iridium. Base Station B can also service Data-Buoys or other nodes in the network,
using our communication protocols. The Base-stations run software which allows packets to be sent/received from Gliders and other mobile or static nodes. In our setup, the Freewave modems are setup such that all Base stations are “Masters” while all Gliders are “Slaves”. Any glider can connect to any “free” base-station. Links persist for as long as data is being sent to the glider, or until external factors result in a dropped link. We have also observed connections getting swapped between base-stations.

In normal glider operations, the glider’s freewave is configured such that it can connect to only one freewave at a time. The other side, which we shall refer to as the shore station, consists of a freewave attached to a computer running a software from Webb Research called the DockServer. The glider can also be operated via any terminal client such as Minicom or HyperTerminal since it provides a human-readable interface via ASCII strings. This also means however, that there is no inherent packetization of data being performed on the glider since it assumes that it is always connected to a single computer via either of its two links (Freewave or Iridium). This situation, coupled with the fact that the Freewaves (at the time of writing this paper), do not have a mode of operation, which can independently handle hand-offs between modems, mean that it is difficult to build a reliable end-to-end system to communicate with the gliders without using packetization for the identification of sources and destinations. Any disruption in communications due to loss of a link or a reconnection of the glider via a new link (as shown in the figure), will result in data getting garbled. As an illustration, consider glider 2 in Fig. 1. This glider is in the range of both Base-Station B and Base Station C. Hence, due to waves or excessive pitching and rolling, it can lose connectivity and switch base-stations. Consider a scenario where glider 3 was also at the surface at the same time and happened to connect to Base Station C, as soon as glider 2 got disconnected from it and connected to B. In this case, it will be difficult even for a human operator monitoring both Base-stations to distinguish information from each glider. Z-modem file transfers can potentially get corrupted.

Adding an additional computing platform to the glider to handle only the communications and act as a bridge between the glider’s control computer and the freewave was chosen, since it is a minimally intrusive way of adding new communication capabilities to the glider. We were concerned that modifying the persistor code, to perform more tasks could de-stabilize the control on the glider by pushing its own computer beyond its limits.

Fig. 1: Communication System Overview
We chose a Gumstix because besides being very small, this computer can run a capable operating system like Linux, consumes very little power (<120mA @5V), and has good interfacing capabilities. Fig. 2 shows the physical modifications to the glider due to the addition of the Gumstix. We need to make only 5 modifications to the glider to allow the glider to communicate with an external computer. Although the gumstix consumes more power than the persistor alone, we have designed the system such that it gets powered up along with the Freewave modem - a feature that ensures that it gets automatically turned on at the surface, while keeping power-consumption the same as it would during normal glider operations.

We do this by using a set of networked base-stations (Fig. 1) which are essentially PCs running Linux, which are connected to the Internet and also have a serial link to a Freewave modem. The figure shows one such base-station, as well as the Freewave modem and antenna connected to it. These sites run communication software which relays datagrams between the glider and a central data-aggregation and Command/Control server. Communications between these base-stations and the Central server take place via traditional TCP/IP communications. We store data from the gliders in a data-base maintained on this server, and also have a secure web-based glider control interface which provides a user with an easy-to-use method of controlling the glider as well as uploading/downloading files to/from the glider.

On the glider, the Gumstix intercepts all messages to and from the glider persistor and the Freewave modem. Our software, running on the gumstix, parses the ASCII strings from the glider and sends necessary information to shore using our packet protocol. It also transfers sensor data files from the Persistor and compresses them and forwards them to the shore station. If communication with the main server via FreeWave is unavailable, the glider falls back to Iridium for reporting.

**MAS 02. 4 Results and Accomplishments**

At the time of writing this report, we have conducted three field tests with a single glider. The first of these tests was conducted using our base-station at Catalina Island on November 2008.

1. **Catalina Island (Nov 2008)**

The main objective of this test was to verify that the Glider was operating correctly with the addition of the Gumstix computer. The secondary objective was to get measurements on the range of the FreeWave communications with the Glider. The glider was loosely tethered to a boat which followed to around just in case
there was any problem with the hardware. The Glider’s radio connected to a radio on Catalina and to a radio aboard the boat. When no radio connection was available it connected to USC via Iridium.

2. Pt. Fermin (Jan 2009)
The focus of this test was to gather data on the range and quality of the FreeWave radio communications as well as test the whole system from end to end. An operator was present at USC to communicate with the Glider through the Base Stations and the boat also had a FreeWave modem in case. Unfortunately the radio at Pt. Fermin was broken at this time so the communication range was much shorter than expected, or just about 2 miles, so the test had to be repeated.

3. Pt. Fermin (Feb 2009)
After the radio antenna at Pt. Fermin had been fixed the Glider was put in the water at three distances from Pt. Fermin: 2.5 miles, 6 miles and 8 miles, which is also 12 miles from the Catalina Base Station. At each location, the Glider was asked to do a short dive and, depending on the quality of the communications link, file transfers were done between Glider and shore. (At the 6 mile point we successfully re-tasked the Glider through our network when we sent it a new mission from USC and ran it successfully.).

We have also developed a Web-based GUI which allows users to easily plan new missions for gliders, as well as visualize them as they surface. It displays critical glider information like battery levels, glider location, abort conditions and other health indicators. The mission planner also has important information such as shipping lanes, and bathymetric iso-bath overlays which help users plan safer trajectories for gliders when done manually. Fig. 3 is a screenshot of our Glider Control User Interface which allows visualization of glider information for any authenticated users of the system. This web-based UI receives information from the base-stations via a data-base interface which is itself populated through a server which communicates with the base-stations via the internet.

These tests show that our system is capable of allowing gliders to be operated in our region of interest – the Southern California Bight.
MAS 02. 5 Future work

We are still in the process of testing the functionality of our system. At present we have two freewave nodes, but we expect our system to expand to include all of the nodes. Setting up the rest of this infrastructure will enable us to have much better coverage and increase the area within which we can communicate with the gliders using Freewave modems only. We have also got to test our communications system to ensure that it works with several gliders having surfaced simultaneously. We would also like to expand our communications infrastructure to include several other nodes such as data-buoys and boats carrying sensors and freewave modems, so that they can relay their data into our network. Since boats are always at the surface, this will allow us to collect much more data in near real-time. Tests of using our system between base-stations and boats have yielded very good results so far (>20 miles) of reasonably strong data-links.