Design of a Small, Cheap UUV for Under-Ship Inspection and Salvage

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Abstract

Small UUVs have a wide variety of uses including inspection, instrument placement, specimen gathering and salvage. However the uses of these UUVs has been limited by two factors:

1. Cost – UUVs have been traditionally quite expensive, putting them well out of the reach of the traditional marine operator.
2. Wires – Most UUVs trail a cable for power, control, and video back to the operator. The cable makes it difficult to use the UUV in kelp, or in the presence of nets or other UUVs.

This paper describes the design and function of a small (less than 10kg) and inexpensive UUV that is given a mission description and then carries out that mission autonomously. The UUV can home in on a beacon, assuring its recovery at the end of the mission. This vehicle can be used for everything from inspecting a fouled propeller to placing a piece of equipment on the ocean floor in the middle of a kelp forest.

Introduction

UUVs are used for a variety of tasks that require a wide range of capabilities. The systems that have been constructed are typically fairly large[1] and expensive. In part this is due to the large number of capabilities that are built into the vehicles.

It is our belief that a useful UUV could exist that would have a very limited set of operating capabilities, and that a UUV that met those capabilities could be produced at relatively low cost. The limits we are setting for the purposes of this paper are:

- Shallow water (depths of less than 30m)
- Calm water (currents of less than 2 knots)
- Clearly defined mission goals
- Low cost
- No need for real time commands
- No need for real time video

[1] while most UUVs are small when compared to standard submersibles, they are larger and certainly heavier than most mobile robots.

The last three items above are unusual for a UUV. Almost all UUVs run a tether back to the surface for sending video, receiving commands, and often power is run over the tether as well. However, if a task domain is chosen where real time commands and video are not needed then the tether can be eliminated. The only challenge that remains is controlling the robot without continuous telemetry.

Fortunately, behavioral control technology [2] has advanced to the point where autonomous control can be added to a UUV, and is sufficient for carrying out many types of missions. Behavior control has been used successfully on UUVs before, but in [1] it was used to safe the vehicle from collisions, and in [3] it was used to control a legged bottom crawling vehicle. In [4] behavior control was suggested as part of the overall architecture in a much more complex UUV. We are unaware of any work to use behavior control to minimize the size and cost of a UUV the way it has been used to minimize these factors in other types of exploration robots [6].

The types of missions we will address with this system are simple inspection of a well defined area, such as the hull of a ship, or simple rendezvous with a well defined target. In both instances, well defined means that the target or hull are readily detectable by the sensors onboard the vehicle.

No attempt is made in this system to keep track of the robot's absolute position, or to follow a specific course during the mission. The targets and areas of inspection are defined by their visual characteristics: brightness and color, or their contrast to the rest of the environment.

The Vehicle

Our vehicle, *DRIP*[2], is 44.5cm in length, has a maximum diameter of 12cm and displaces 3.8l of water. Like all of KIPR's robots, the use of off the shelf parts

[2] The Digitally-controlled Research Immersible Prototype.

are maximized to increase reliability and reduce cost (see [5,7]).

The hull of *DRIP* is constructed from PVC sewer pipe and a 12v dive light. The resulting structure is shown in Figure 1. This combination of parts allows much of the hull to be disassembled for cleaning and maintenance. The dive light casing allows easy access to the electronics and batteries through the unscrewable lexan bezel at the front. The three position switch from the light has been utilized to act as a main power and computer reset switch. The clear lexan front allows the sensors to have a clear view of the environment.

Figure 1: The *DRIP* UUV

The propulsion and steering system is provided by a set of model airplane refueling pumps, shown in Figure 2. These in-line, reversible pumps are used to move the vehicle forwards and backwards, as well as controlling yaw.

Pitch is controlled by changing the CG. A weight is moved along the inside of the vehicle by a motor and ball screw arrangement. The vehicle is weighted to be neutrally buoyant (a very slight positive buoyancy is maintained). Depth is controlled by altering pitch and thrusting forward or in reverse. Approximated hovering can be maintained by maintaining a slight pitch and thrusting forward and back as needed.

Power is supplied by four standard 1.5aH-7.2v nicad battery packs. The motors are operated at approximately 14 volts. The power for the electronics is regulated at 12 volts.

On-board computation is supplied by a Vesta 68332 processor board (Figure 3) running the ARC real-time operating system. The processor controls the pumps and motors through a relay board. Speed control of the motors has not been implemented. However speed of the vehicle can be controlled by the number of pumps that have been engaged.

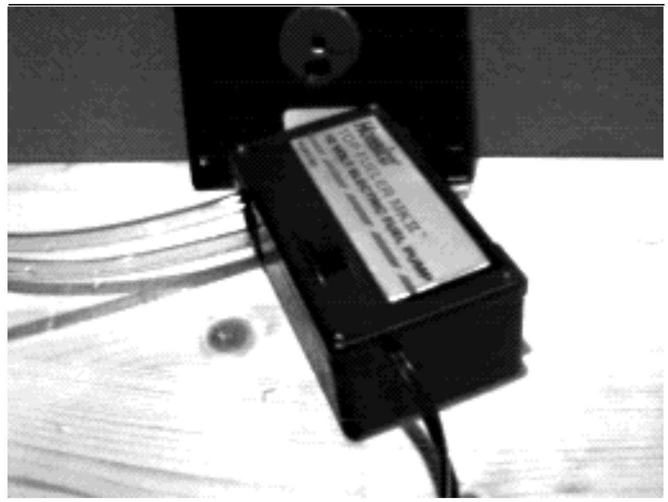

Figure 2: *DRIP's* Propulsion Pump

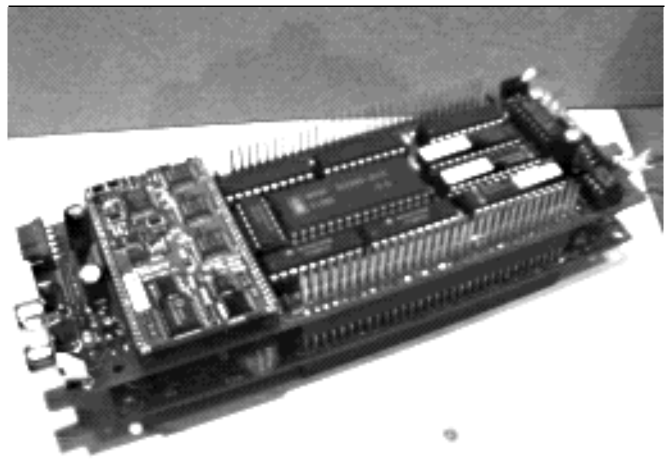

Figure 3: The Cognachrome Color Tracker mounted on the Vesta Processor Board

The standard sensor suite for *DRIP* consists of an array of photo transistors, and an IR proximity sensor. Additionally, there are several proprioceptive sensors for monitoring the internal state of the robot. A Chinon color video camera (shown in Figure 4 is included. Its output is fed through a Cognachrome color processing board (see Figure 3). This allows real-time color tracking for finding objects with preset color properties. The color table can automatically be adjusted during the robot's operation to handle the changes in color absorption due to differing distances between the camera and the object being tracked.

Current Status and Near-Term Plans

As of this writing, assembly of *DRIP* is almost complete. All the components have been individually test-

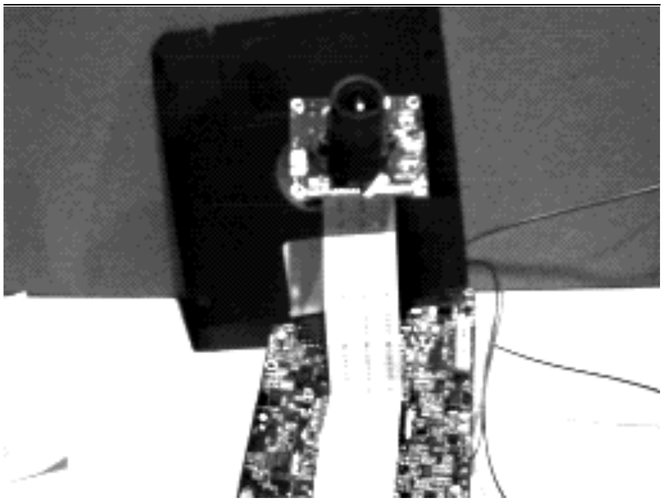

Figure 4: The color camera (3.5" floppy in background for scale)

ed. The first full-up systems tests in the water should take place in the next few weeks. The testing will take place in a local neutral buoyancy tank which is fifty feet in diameter and twenty-five feet deep.

Once the system is fully operational, we plan to test *DRIP* in a variety of scenarios including:

- Find the dive light. In this scenario the robot searches out a dropped dive light and rendezvous with it. This is a prelude to a salvage task.
- Follow the diver. The robot tracks the colors of a particular diver and follows them around while avoiding other divers and objects.
- Hide under the boat. In this scenario, the robot stays near but under a boat or other platform on the surface. This is a prelude to a hull inspection task.

The parts costs of the complete vehicle are under $3000. Approximately two-thirds of that cost goes to the color tracking system. If low-cost sensors can be found for useful missions, then copies of *DRIP* could be reproduced at almost disposable prices.

Conclusions

Some UUV operations can be done without continuous operator intervention. Once this assumption is made, the umbilical that follows almost all UUVs can be cut, freeing the UUV, and eliminating much of the overhead of both the UUV and its operations. A semi-autonomous UUV can be constructed for very low-cost. We hope to prove over the next several months that such a UUV will have high utility.

References

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