Mapping Shallow Water Areas Using a Remotely Operated Vessel

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Abstract: - Data collection in shallow water areas presents several challenges to the scientist. In addition to being redundant and time consuming, this task when performed manually has a high probability of disturbing the test area. Obstacles that are encountered in such environments include difficulty in covering large territories and the presence of inaccessible areas due to a variety of reasons, such as soft bottoms or contamination. There is also a high probability of disturbing the test area while placing the sensors. This paper describes the development of a remotely operated boat and shows how it was used to map shallow water areas.

Key-Words: Wireless control, remote control, autonomous navigation, mapping sea bottom

1 Introduction

Research in aquatic environments presents several challenges to the scientist. One of the pressing issues is how to efficiently and reliably gather data in shallow water areas. This project was initiated by the Department of Computing and Mathematical Sciences (CAMS) and the Division of Nearshore Research (DNR) at Texas A&M University-Corpus Christi (A&M-CC) to produce a remotely operated vessel that aids in the monitoring and study of the water quality of coastal waterways, estuaries, and bays. Many of these bodies of water are relatively shallow and prevent navigation of a regular size craft with a human operator.

To gather data about the aquatic environment of a particular estuary, a researcher could venture out into the water (either by boat or with the assistance of waders) along with a collection of instruments, taking measurements and recording results. This is a straight forward and simple approach provided one is interested in a relatively small area of study. But what happens when the problem begins to increase in scale or complexity? Perhaps, one needs to study an estuary spanning several square miles. In such a case, one is faced with two options: (1) divide the task up and hire extra researchers, or (2) somehow increase the efficiency and speed with which one works.

Autonomous data logging is another approach. One example is the TCOON system that is in place along the Texas coast [1]. TCOON's network of fixed observation posts works well for monitoring specific locations continuously. For problems where a researcher is interested in an entire area at a specific time, however, a mobile solution is required. A number of research centers have been developing autonomous boats [2–4]. These boats, however, require course planning prior to deployment. As a result, the course is not easily changed once the boat is in the water.

The additional benefit of a mobile system versus a "by hand" approach is the consistency of the results. All readings are taken by the same sensor(s) and all data is processed by the same algorithms. Moreover, the data is easily and consistently entered into a database for analysis? This last step is particularly significant if the system needs to operate in real-time.

Shallow water areas, 12” to 18” inch deep, are of specific concern to this project since they are not always accessible by waders (too deep in some areas) or boats (too shallow in some other areas). Moreover, both waders and boats can have a substantial impact on the area of study.

In an attempt to address the problem of Data Logging in a Shallow Water Environment, researchers at A&M-CC proposed a vehicle that satisfies the following operational requirements: (a) The boat is remotely controlled within the operator’s line of sight, (b) It is small and easy to transport in the back of a truck without extra towing equipment, (c) It is stable enough to resist waves and wind, (d) It has the ability to travel through areas with a draft as small as 6 inches, (e) It has sensors to detect objects from all directions (front, sides, back, and bottom), and (f) It transmits data wirelessly to a docking and control station in real-time.

Two boats have been designed and constructed so far. The first prototype provided an excellent starting point but had several limitations that needed to be addressed [6]. The boat had a flat-bottom and was powered by a small trolling motor. A DC motor was attached to the shaft of the trolling motor, allowing the thrust of the motor to be directed. This redirection of thrust allowed the boat to be turned. The problems associated with this design were evident during sea trials. The boat, though relatively heavy, cannot track against the wind and waves and has great difficulty executing a controlled turn or making subtle course adjustments. In addition, the control system, based on RC servo/transmitter technologies, is subject to the inherent limitations of these technologies. Second, the design did not allow programmatic control of the vessel. All details about the vessel’s state (speed, position, and heading) are observed by the operator visually, rather than recorded by the vessel and forwarded to the operator.

The second prototype was a completely new design and corrected several of the problems that troubled the first prototype [7]. The only similarity in the design of the two prototypes was that they both used the same trolling motor for propulsion. A cylindrical hull, along with a pontoon on each side of the hull, was used to make up the body of the boat. This prototype also incorporated a new control system that helped overcome many of the limitations of the first prototype. The current prototype is capable of moving the rudder through a limited range of rudder positions, from 45° left of center to 45° right of center. This paper will presents results of mapping shallow water areas using this boat.

2 Boat Design

The current boat is shown in Fig. 1. The shape of the hull was selected to increase stability and reduce the area of the boat that was exposed to wind. This ROV is made of 12” outside diameter (o.d.) PVC pipe and has two outriggers that are constructed of 5” o.d. PVC pipe. Total length is approximately 60 inches, the width is around 46 inches, and the height is approximately 36 inches.

Fig. 1 Current boat chassis

The main body of the craft contains the controller with its 16 attached modules, one 12-volt marine battery, GPS transceiver, one 2hp trolling motor, and a rudder control system that contains a servo motor. An aluminum beam is placed along the length of the craft to serve as a platform for the processors, batteries, trolling motor and rudder control mechanisms as well as the GPS system. The vehicle weighs approximately 180 pounds.

3 Control System

The control system is built around a powerful controller by National Instruments (NI), shown in Fig. 2. The software was developed using the LabVIEW Real Time (RT) environment.

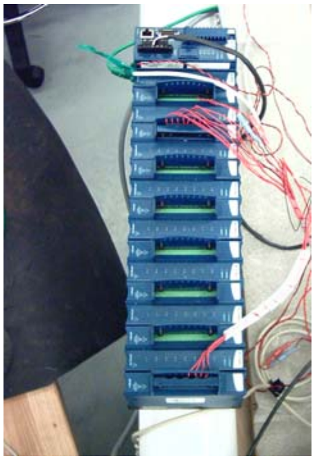

Fig. 2 Controller and its modules

3.1 Control system hardware

The National Instruments cFP-2020 was chosen as the controller for the ROV [8]. The cFP-2020 communicates by way of an auto configuring 10/100 Ethernet connection and offers three RS232 serial ports, an RS485 port, as well as discrete digital input/output terminals. Another asset of the cFP-2020 is the LabVIEW RT software that is embedded in the controller. With LabVIEW RT, applications can be downloaded to the controller and run independently of a PC.

The NI cFP-BP-8, a backplane, is used to connect several modules to the cFP-2020 controller. There are four different modules connected to the backplane and controller. The first module is the cFP-AI-110, which is an 8-channel analog input module for direct measurement of millivolt, low voltage, or milliampere current signals. It features filtered low-noise analog inputs, and incorporates 16-bit resolution. The inclinometer is connected to one of these modules, while the rotary encoder is connected to the other.

The cFP-PWM-520 is the second module connected to the backplane, and is a pulse width modulation (PWM) output module. This module is not currently used. A relay module is also connected on the backplane. It is the cFP-RLY-421, and is not currently used. The final expansion module used is the analog output module cFP-AO-210. The cFP-AO-210 includes over-current detection for wiring and sensor troubleshooting, as well as short-circuit protection for wiring errors. This module is used to connect the motor control circuits to the controller.

3.1.1 GPS

A Garmin 17N is used. This is a waterproof model designed for marine operation. The GPS data is based on the NMEA standard. NMEA stands for National Marine Electronics Association—the standards body that shepherds the standard by which marine navigational devices communicate [9]. The 17N sensor can transmit positional information as often as once a second and at speeds of up to 9600 baud. Moreover, the unit can be programmed to output as many or as few different GPS sentences as the user requires.

3.1.2 Depth sensor

The depth sensor is a IDT800-P17-RETR manufactured by Airmar. It is capable of measuring a minimum depth of 0.4 meters. The sensor also measures the temperature of the water in degrees Celsius. Just like the GPS, the depth sensor sends its data using the NMEA standard.

3.1.3 Inclinometer

SignalQuest's MEMS Inclinometer is used to provide constant monitoring of the ROV's pitch and roll. This small chip provides measurement of 180 degrees of pitch and 360 degrees of roll to one degree of accuracy.

3.1.4 Rotary encoder

In order to get feedback about the position of the rudder, a rotary encoder was employed. The device was built by BEI, uses the Gray code, and features 8 bit resolution.

The rotary encoder was mounted directly above the rudder and connected to the rudder shaft by way of a flexible coupling.

3.1.5 Radio modems

The ROV's wireless transmission system is composed of two 900MHz, spread spectrum radio modems manufactured by Freewave. These transceivers use the RS-232 protocol to interface with the cFP-2020 controller as well as the user's computer. A 9-pin serial cable is used to connect the transceiver to the COM1 port on the cFP-2020 controller. The other transceiver is powered using a small 12 volt battery, and is connected using a 9-pin serial cable to the user's laptop.

3.1.6 Motor driver circuits

Both the rudder and the propeller operate at 12V, but they require a great deal of current, far more than the controller can handle. Furthermore, it is desirable to be able to control the speed of both motors. For these reasons, two driver circuits were created to control the speed and direction of both the rudder and propeller motors. The circuits differ only in the way they connect to the controller and accomplish their tasks using pulse width modulation (PWM) to control the speed of the motors. These circuits are built around a MOSFET driver, TD340, and four high current MOSFETs configured in an H-Bridge to direct the flow of current through the motor.

3.2 Control system software

The software for the control system was developed using LabVIEW RT. LabVIEW RT is a standalone platform which means that it does not need a Windows based system to operate on.

From a high level, the software running the control system can be understood as two major loops that run continually. One executes onboard the cFP-2020 controller, transmitting the status of the ROV and handling the commands sent by the user, and the other executes on the user's laptop, displaying the status of the ROV and relaying commands to the vessel. In this way, the control system is very much a distributed system, and as such faces all the challenges of a distributed system—from the unreliability of communications links, to the challenges of synchronizing data between systems.

The flow of control and data signals is illustrated in Fig. 3. The two parameters that the operator controls are the speed of the ROV and its direction.

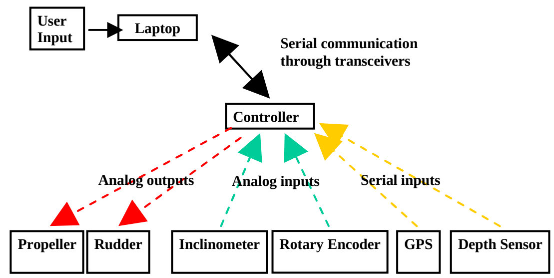

Fig. 3 Data Flow

3.2.1 Graphical user interface (GUI)

The most recent system GUI has the front panel shown in Fig. 4. The vessel's pitch, roll, and rudder position are displayed in real-time. In the upper left hand corner, a grouping of fields displays the GPS position of the ROV, its current true course (labeled "Heading"), and its speed as determined by the GPS. The vertical and horizontal track bars represent the throttle control and rudder control respectively. Near the bottom center of the screen are "Connect" and "Disconnect" buttons along with a dropdown menu to select the COM port that the transceiver is connected to. To connect to the ROV, the user selects the appropriate COM port and presses "Connect". The software begins displaying the status of the boat, updating the text fields and graphics in real-time. The controls also become active, allowing the user to change the speed and direction of the boat's propeller as well as the position of the rudder.

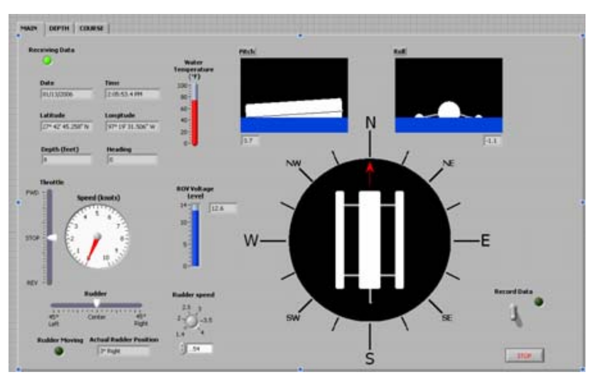

Fig. 4 GUI while ROV is running

To begin moving the boat, the operator uses the mouse to adjust the throttle track bar or use the 'w' and 's' keys. Moving the throttle up, the ROV will move forward at incrementally faster speeds. Returning the throttle to the middle position will stop the motor. Moving the throttle down past the mid point shifts the ROV into reverse.

In order to change the position of the rudder, the user can use the mouse to adjust the rudder track bar or use the 'a' and 'd' keys. Moving the track bar left or right moves the rudder to the "left rudder" or "right rudder" positions (225° and 135° respectively). Centering the control returns the rudder to the "centered" position (180°). To disconnect, the user simply presses the "Disconnect" button.

3.2.2 Embedded LabVIEW RT VIs

As mentioned previously, the code that is embedded in the cFP-2020 controller was developed in LabVIEW RT. The main VI that drives the ROV controls initialization of communication resources, calls the other subVIs that perform the smaller tasks necessary for the ROV to operate, and determines how often these tasks are performed.

4 Testing the Prototype

The initial sea trial of the ROV took place on the 17th of April, 2005. The wind had been blowing at 20 knots for two days, and the sea was choppy even in the protected beach area next to the A&M-CC campus. The ROV was carried into the water and launched while under control of a laptop located onshore. After the vessel was under its own power, it was steered toward the eastern gap in the jetties. The ROV navigated along the jetties, at times obscured from sight by the rocky jetties or waves. The test was successful and the boat's handling was straightforward and responsive. The ROV, however, collected about a cup of water during an hour and a half of sailing.

Recent tests were conducted on January 16, 2006 and March 25, 2006 (see Fig. 5). Fig. 6 shows the course of the boat and Fig. 7 shows the mapped bottom of the area.

Figure 5 ROV under sail

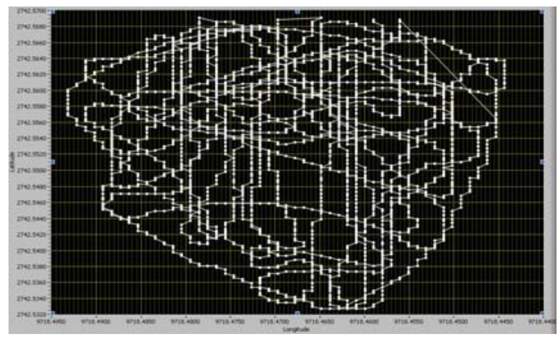

Fig. 6 Navigation Course

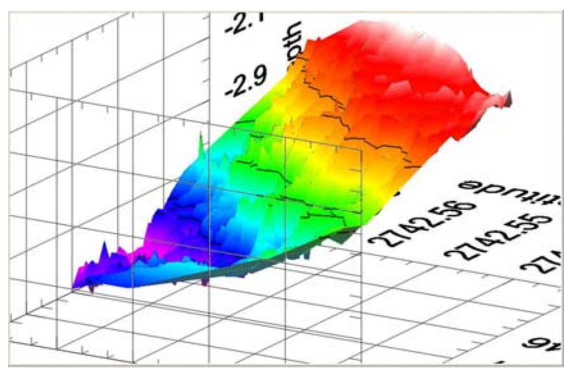

Fig. 7 Depth Map for the course in Fig. 6

5 Future Work

Real-time video is being added to the ROV. The system consists of the Compact Vision System from National Instruments and two cameras. A major aim of the project is to develop functionality that allows the ROV to navigate on its own when given a destination or a series of destinations (waypoints). As this new, programmatically driven control system becomes more mature and the boat chassis in which it is embedded becomes more reliable, autopilot functionality becomes more of a possibility.

6 Conclusion

This paper describes the use of a ROV for wireless data logging and mapping of shallow water areas. The control system allows integrating additional capabilities as well as the foundation for autonomous operation. The boat paves the way for sophisticated data collection systems in shallow water areas and contributes to research in a number of fields, including oceanography, studies of contaminated environments, and hazardous areas.

Acknowledgement

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