Case Study: Unmanned Ocean Vehicles

Opto 22 SNAP PAC Controls a New Type of Marine Vessel

Unmanned ocean vehicles are sometimes referred to as the "satellites of the sea," because they're incredibly durable, operate largely autonomously, navigate long distances, and are used for remote research, exploration, detection, and data collection.

The vehicles designed and built by Payne Kilbourn and his company, Unmanned Ocean Vehicles Inc., are energy scavenging vessels that rely on a combination of wind, photovoltaic (solar), and motion power. Wind is primarily used for propulsion, and as the vehicle moves through the water, it turns an on-board propeller. Just as a hybrid automobile uses the rotation of its tires to generate power for its battery, the rotation of the UOV's propeller generates power that's stored in batteries and used to power the vessel at night or when there's little or no wind. Kilbourn says his UOV can travel and operate for up to two years, performing tasks such as bottom mapping, hurricane and storm tracking, and climate monitoring through the gathering of wind speeds, water temperatures, humidity, barometric pressure, and other variables.

"These vehicles can be outfitted to sense, detect, and perform the same functions as many manned ships," says Kilbourn. "The difference is, the UOV is much more cost effective to operate because it doesn't require fuel, on-board personnel, or provisions. Plus, our vehicles can also be deployed and continue to collect scientific data amidst hurricanes and other conditions where having a manned ship would put lives in jeopardy."

Vehicle Controls

Kilbourn says the sensors and instrumentation used to monitor conditions related to humidity, water temperature, and the like use very little power, so the solar cells, wind, and batteries are usually more than enough to meet all of the vehicle's power needs, including conveying it wherever it needs to go, up or down the coast or out on the open sea.

Of course, for the UOV to operate effectively, a control system is required. So as he developed his 20-foot prototype, Kilbourn looked at a number of PLC-based solutions before settling on Opto 22's SNAP PAC input/output modules and programmable automation controllers. The SNAP PAC System™ is able to handle the large quantity and variety of inputs and outputs needed for power and navigation, as well as sensing, monitoring, and gathering data. In doing so, the SNAP PAC serves as a central controller that utilizes both serial and Ethernet communication to connect to and regulate a multi-vendor team of micro controllers and marine instrumentation, each with its own area of responsibility, including wing (sail) control, steering, and power management.

Wing Control

The UOV has a rigid winged sail, outfitted with solar cells, that must be rotated in order to catch the wind. To do this effectively, a serial connection from the controller to a ComNav® wind meter is used to accurately measure wind speed and wind direction. The SNAP PAC then uses this data in calculations it performs to regulate a Parallax™ BASIC Stamp® microcontroller and stepper motor that adjusts the sail. The PAC also interfaces to an optical sensor used to confirm that the sail has in fact moved to the proper position.

Steering

Another microcontroller moves the UOV's rudder, assuring that the vehicle maintains the proper heading and bearing. At any time, adjustments can be made based on data input from the onboard Tristar GPS system, magnetic compass, or changes performed manually by the UOV operator. Kilbourn himself developed the code needed for the SNAP PAC to translate serial string messages from the GPS system, which communicates using the NMEA 0183 standard[1]. With the translator implemented, the PAC is able to use the GPS data and, as necessary, alter the course to steer, such as when the UOV needs to tack or jibe.[2]

Power Management

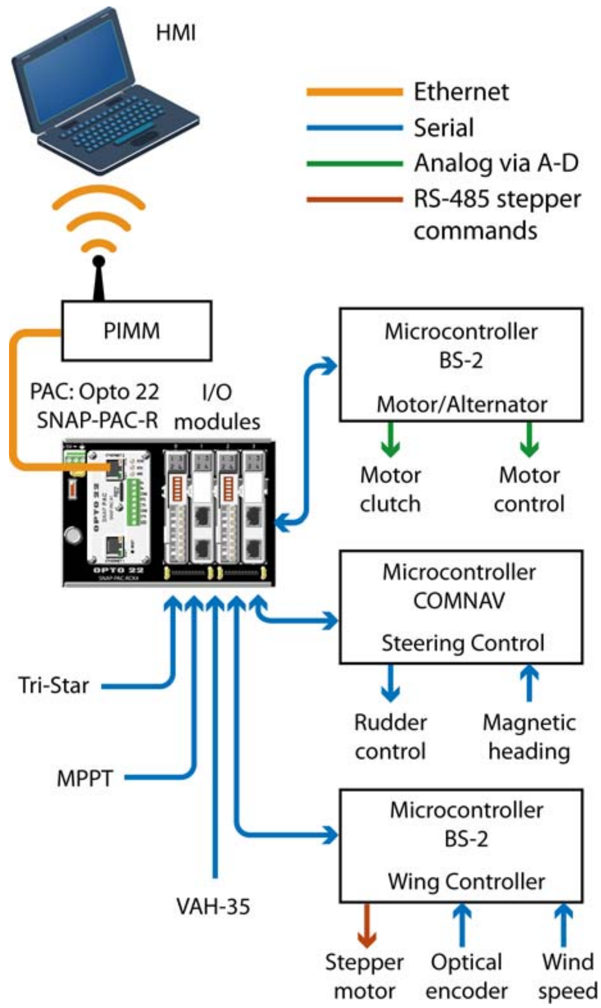
Voltages and current amps from the solar cells are measured and a maximum power point tracking (MPPT) device is used to optimize the sunlight-to-power conversion.

"We use analog input modules to monitor power generation, power consumption, and battery charge, as well as the performance of the MPPT," says Kilbourn. "This ensures that we achieve peak power voltages and that the proper amount of power is output to the batteries to optimize solar power production."

Programming

Kilbourn took advantage of the SNAP PAC's ability to run multiple (up to 16) charts[3] concurrently within a single control program. These charts execute concurrently and all share data.

1. NMEA 0183, defined by and controlled by the National Marine Electronics Association, is a specification for communication amongst marine instrumentation such as echo sounders, sonar, anemometers, autopilot systems, and GPS systems. Under the NMEA 0183 standard, data is sent from one sender to multiple receivers using ASCII-based, serial communication strings.
2. Tack refers to the act of a sailing vessel proceeding in a zigzag fashion as it sails into the wind. Jibe is a sailing maneuver whereby the vessel shifts from one side to the other as it proceeds with the wind.



For example, a chart identified as "Captain" includes all the wind speed monitoring commands and executes the logic needed to determine when to turn the motor on and off, and at what speed it should run. The "Navigator" chart, meanwhile, uses data from the "Captain" as it performs the computations needed to determine the course to steer. The "Navigator" also gauges where the vehicle is with respect to where it's supposed to be.

When creating charts for the UOV, Kilbourn also used OptoScript, a scripting language similar to Visual Basic and C++ that's ideal for programming the complicated mathematical formulas and if-then-else commands the UOV controller must constantly perform in order to operate and navigate through the water on its own.

3. A chart is a series of commands in the form of a flowchart. Many charts are used together to develop a control program.

Kilbourn, a retired U.S. Navy Captain, has no background in control engineering but used the PAC Project manual and online screencast tutorials to teach himself all he needed to know.

Data Logging and Transmission

A Payload Interface Master Module (PIMM) from Trident Systems interfacing to the PAC allows the UOV to transmit Ethernet data via high-frequency radio. Other PIMMs connect to onshore computers, and if the UOV is operating near the coast, real-time instrument data from the vehicle is aggregated from the SNAP PAC wirelessly over radio networks. If the vehicle is operating in areas like San Francisco Bay, which has 100% phone coverage, everyday cellular connections can be used. When the UOV is out to sea, satellite communication is used. Once the connection is established, the data is presented in either graphical or tabular format in easy-to-read human-machine interface screens. At all times, operators have full access to the control program and can modify any of the UOV's functions, including changing course, repositioning the sail, and adjusting speed. Kilbourn says that for testing purposes, he even sometimes sends simulated sensor data to the controller to see how the UOV responds and performs.

"In addition to the control parameters, we can change the vehicle's monitoring and data acquisition requirements on the fly," Kilbourn says. "We're able to make adjustments to the instrumentation and sensor interfaces and redefine the variables we want to track, how often measurements are taken, and most importantly, how often data is sent to and from the vehicle."

This ability to specify and program the amount of data sent has proven extremely valuable. The wind direction, for instance, is tracked and sent almost continuously, while battery state of charge needs to be transmitted only about every ten minutes.

Unmanned Ocean Vehicles' prototype, currently based on the Potomac River near Washington D.C., has already garnered the attention of the U.S. Navy, and the company has received funding and development contracts from the Office of Naval Research and the Naval Sea Systems Command. Because his UOV design is so scalable (lengths from 12 to 50 feet) and new potential applications like homeland security and oil spill tracking are emerging all the time, Kilbourn's UOVs stand ready to fill a need for self operating, rugged, low-cost vessels capable of hosting high-tech data gathering and communication systems for scientific and military purposes.

About Opto 22

Opto 22 develops and manufactures hardware and software for applications involving industrial automation and control, remote monitoring, and data acquisition. Opto 22 products use standard, commercially available networking and computer technologies and have an established reputation worldwide for ease-of-use, innovation, quality, and reliability. Opto 22 products are used by automation end-users, OEMs, and information technology and operations personnel in over 10,000 installations worldwide. The company was founded in 1974 and is privately held in Temecula, California, USA. Opto 22 products are available through a global network of distributors and system integrators. For more information, contact Opto 22 headquarters at +1-951-695-3000 or visit www.opto22.com.