DYNAMIC POSITIONING CONFERENCE

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Sensors

Dynamic Positioning and WROVs: A Productive Union

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Abstract

Dynamic positioning (DP) has been used by surface vessels for over 20 years with great success. No one can now imagine doing typical oil field construction work from a vessel that lacks this capability. DP has also increased the capabilities of AUVs. However, DP has generally not been used on commercial work-class remotely operated vehicles (WROVs), though several research organizations (such as Woods Hole Oceanographic Institution) have implemented DP on their ROVs. Implementing DP on a WROV produces the same effect that DP has in other realms: improved safety and efficiency.

This paper describes the DP system of the Schilling Robotics Quest WROV. The paper discusses real-world WROV tasks that have been performed with Quest, and notes the benefits provided by the union of the WROV and DP.

Specifically, the paper discusses:

- The characteristics of a DP-capable WROV control system
- DP implementation on the Quest WROV
- Use of DP to perform typical WROV tasks
- The future of DP on WROVs

Characteristics of a DP-Capable WROV Control System

In this paper, DP refers to a vehicle control system with the following characteristics:

- Using its own propulsion system and sensors, the vehicle can remain stationary (within a radius of a decimeter in x and y about the set point) for an unlimited time. (However, the maximum power of the propulsion system is a limiting factor in compensating for ocean currents.)
- The vehicle can accurately displace (move to) another location in the x, y, and z axes, and upon arriving at the new location, can remain stationary. Furthermore, the vehicle can perform this displacement while in an arbitrary yaw orientation.
- The vehicle can automatically follow a set of way points created either statically or dynamically. An example of a statically created way point path is a preplanned path using survey data. An example of a dynamically created way point path is pipe or cable tracking.
- The vehicle can accurately report the distance and vector between two points on or near the seafloor.

Figure 1 In station keeping, the system's ability to withstand currents is limited by the propulsion power of the WROV

- The vehicle can adjust the DP set point using a proportional input device. This “rate mode” allows the pilot to fly normally until he nulls the input device, at which point the vehicle automatically holds position.

DP on the Quest WROV

To perform DP, the Quest WROV control system uses sensors, a control model, and actuation equipment.

Sensors

DP on the Quest WROV is built around a Doppler velocity log (DVL), which supplies information about the WROV’s velocity relative to the seafloor. The DVL also supplies altitude and water velocity information. The standard DVL used is the RD Instruments Workhorse 1200, which pings at 1200 kHz . The update rate to the control system is about 9 Hz and varies slightly depending on the range to the seafloor. This DVL has a range of about 35 m; other models with lower ping frequencies have a greater range.

Space considerations prevent the DVL from being mounted at the vehicle's center. Instead, the DVL is mounted on the centerline but near the vehicle front, and software is used to remove the translational components generated by yaw movements so that the DVL appears to the system to be at the vehicle's rotational center.

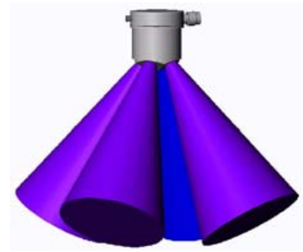

Figure 2 A Doppler velocity log provides data for dynamic positioning

The system is augmented by a motion reference unit (MRU) that provides pitch and roll angles; pitch, roll and yaw rates; and x, y, and z accelerations. The MRU is a Crossbow 700CA model, and is sampled at 40 Hz. The pitch and roll angles are used to correct the range data supplied by the DVL, and to provide the basis for the body-to-inertial-frame transformation. The currently fielded Quest systems use simple filtering, but do not integrate data from the different sensors. The current version applies Kalman filters to the sensor suite, and this appears to provide significant benefit in simulations and pool tests.

Control Model

Numerous models are available for controlling both position tracking and trajectory tracking of robotic underwater vehicles.[1] These models include Linear Control- PD and PID, Nonlinear with Exact Linearization, and Nonlinear without Linearization. The last two also have adaptive models. The Quest WROV uses the PID model with further modeling of the actuation system, but no attempt is made to model the drag, Coriolis force, or buoyancy force.

The Quest WROV uses a body-frame-to-inertial-frame linear transformation based on the angles supplied by the MRU. The control system sums all the forces acting on the system and creates a resultant thrust vector. The system uses an affine transformation that decomposes the resultant thrust vector into the components that are used to drive individual thrusters. The system uses a thrust-to-speed transformation, ensuring that each thruster supplies the correct amount of thrust.

The control system uses closed-loop control of both position and velocity. The former is commonly used. The latter can be used to apply a dynamic brake to the system, such as when the pilot nulls the input control device. The control system also provides pitch and roll compensation, producing a very stable platform. The system incorporates some *a priori* knowledge, such as knowing that the vehicle will pitch up when commanded forward. The system injects a force to counter this pitch moment, keeping the platform stable under hard accelerations.

The system also uses a proprietary trajectory generator based on velocity tracking. Field testing and field reports indicate that the vehicle tracks very well, never deviating more than ±1 m from the desired path in cross currents. Field reports also indicate that the trajectory generator is accurate, performing moves of 60 m or more within a decimeter of the desired destination.

Actuation

Both the electric Quest WROV and the Quest Ultraheavy-Duty hydraulic vehicle use seven thrusters, four mounted laterally and three mounted vertically. The vertical thrusters provide both vertical movement and dynamic control over vehicle pitch and roll.

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[1] David A. Smallwood and Louis L. Whitcomb, "Model-Based Dynamic Positioning of Underwater Robotic Vehicles: Theory and Experiment," *IEEE Journal of Oceanic Engineering*, Vol. 29, No. 1 (January 2004).