The StationKeep™ Function: Dynamic Positioning for Remotely Operated Vehicles

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As the subsea industry has moved into deep/ultradeep water, remotely operated vehicles (ROVs) have become absolutely necessary to support such tasks as construction support, geotechnical surveys, scientific research, and oil exploration and production. The reliance on ROVs to work in these depths drives a requirement for them to be reliable and as operationally effective as possible.

As powerful and capable as today's vehicles are, their operational effectiveness still greatly relies on the human operator. This paper discusses an advanced control system using a high-performance Doppler velocity log sensor to augment the pilot's expertise by providing dynamic ROV positioning, resulting in significantly improved operational effectiveness.

TYPICAL CONTROL SYSTEM CAPABILITIES

In today's ROV systems, the control system has been treated as an afterthought by many manufacturers. Frequently, the key focus when concepting a "new generation" vehicle has been the vehicle's hardware and electrical interface capabilities. While these are, of course, important areas, the hardware's ease of use is in many ways an equally important factor, and the control system is a key area in designing a system that is straightforward to use.

THE ADVANTAGES OF "INTELLIGENT" CONTROL SYSTEMS

The relatively recent and successful introduction of autonomous underwater vehicles (AUVs) to the commercial industry has proven that AUVs can perform an increasing list of tasks in a significantly shorter time than ROVs. While ROVs can perform seemingly simple tasks, such as seabed surveys, in days or weeks, AUVs can be deployed, left to perform their task in hours or days, and recovered upon completion with minimal, if any, human intervention during the task.

While AUVs continue to provide further capability, the need for telepresence, or human control, still exists for complex tasks, from performing hot stabs on a subsea manifold to collecting sample organisms under Antarctic ice.

As the ocean industry moves into increasingly deep water, the ROV is still an indispensable tool. With the increase in operational depth, the reliability of these tools is critical. If an ROV fails during operations in 100 meters, the vehicle can be recovered relatively quickly, repaired, and deployed back to working depth in a reasonable time. When operating in water depths of 3,000 meters and below, however, a vehicle failure causes significant downtime due to the greater recovery time—which can range from as little as 30 minutes to hours, depending on handling system capabilities. With production, exploration, and support vessel operations now relying so heavily on ROVs, downtime can cost millions of dollars.

To address this reliability issue, ROV manufacturers have continued to improve their hardware, removing failure points wherever possible. As a result, ROV systems are generally considered to be reliable (though there is acknowledged room for improvement).

With equipment reliability generally moving in the right direction, the next step is to examine the other main contributing factor to an ROV job's success: the operator. Pilots and technicians in today's industry are under significant pressure to perform a wide range of tasks—from the tedious to the very complex—in minimal time and with maximum results. Pilots are expected to understand the job requirements and to use all available tools to perform the job as efficiently and effectively as possible.

With the move into ultradeep water, ROVs are loaded with as much tooling and payload as possible, to avoid recovering and redeploying the vehicle simply to reconfigure it for different tasks. Today's vehicles must be able to take everything they need to perform all necessary tasks in a single deployment. The pilot must also be experienced and capable enough to operate all of these tools, in addition to flying the vehicle.

The logical conclusion to these challenges is that technology must enable the pilot to focus on the tasks at hand as effectively as possible. As has been proven with AUVs, the technology is available to let the pilot "release control" of the vehicle so that he can focus on required tasks. One such technology integrates a Doppler velocity log into an intelligent control system, to supply vehicle position and speed information relative to the seafloor.

THE STATIONKEEP™ FUNCTION

The Doppler velocity log (DVL) sensor has been successfully used for many years in applications such as surface vehicle navigation; hydrographic, geophysical, and oceanographic survey positioning; LBL and USBL position aiding; mine countermeasure operations; and dredge spoils tracking. Until relatively recently, however, most attempts to integrate this sensor into a commercial ROV have simply provided the operator with additional speed information relative to the seafloor.

While this information can certainly be useful to the operator for positioning purposes, it is far more useful when integrated with a control system that can put the data to work.

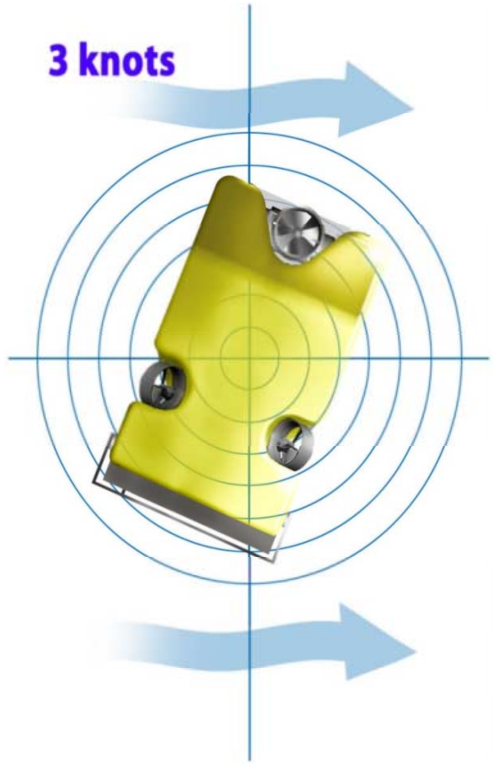
DVL sensors, such as the RDI Workhorse Navigator, can provide a significant amount of information, including bottom and/or water track velocity, altitude, temperature, heading, tilt, acoustic echo intensity, and even pressure and depth.

Schilling Robotics has successfully integrated the DVL into the QUEST ROV product line. In conjunction with the Remote Systems Engine™ control hardware and software components, the sensor has been used for increasingly reliable and autonomous vehicle operation.

For the QUEST ROV, both the bottom track and the altitude information provided by the DVL are integrated into the software control system to provide the vehicle with very accurate positioning information relative to the seafloor. The control system uses this information, in addition to data provided by the onboard motion reference unit, to offer an automatic operation mode. When this mode is selected, the vehicle automatically assumes flight control and maintains position in the X, Y, and Z axes. This auto mode is called StationKeep™.

The benefit of StationKeep™ is immediately recognized by every QUEST operator. For example, without StationKeep™, observation tasks such as drill support that require holding position for hours or even days require the pilot to (1) manually control the vehicle throughout the task, (2) to grasp a structure to hold position, or (3) to physically land the vehicle on the seabed. While these options certainly work in many cases, each method could have unintended consequences, such as damage to the structure being observed, stirring up the seabed and thus decreasing visibility, or simply becoming unstable due to operator fatigue.

With the StationKeep™ function, the operator can manually position the vehicle, invoke the auto mode, and release control. The QUEST vehicle control system not only maintains the position of the vehicle relative to the seafloor, but it automatically controls the pitch and roll of the platform, which is critical to accurately focussing a camera on a specific target or performing a delicate manipulator task.



The ability of the vehicle to hold station continues to present advantages in above-zero current conditions. In the absence of a current, an experienced operator with a well-tuned ROV can perform a task with minimal flight control, either by using the vehicle trim to his advantage, or by manually adjusting the thrust slightly in each axis. In water currents, however, this becomes increasingly difficult, and typically one operator must be solely responsible for maintaining vehicle position while a second focuses on the task at hand. With the StationKeep™ function, the vehicle automatically reacts to external forces (such as current) to maintain position. Heading, altitude, and position are all maintained automatically, allowing the operator to focus on the task from an exceptionally stable platform.

Visibility can also significantly affect a pilot's ability to perform tasks with an ROV. When visibility is low or is periodically completely lost, the pilot can become disoriented. He will at best lose position and spending valuable time reacquiring a target, or at worst allow the vehicle to drift into subsea equipment, possibly damaging the vehicle or the subsea hardware. Experienced pilots can fly the vehicle and maintain position in low-to-nil visibility using instruments alone. However, this situation is very stressful for even the most talented and experienced pilots, resulting in fatigue that can eventually cause mistakes. Providing the pilot with the option to invoke the StationKeep™ mode allows him to hand over vehicle control to the control system, eliminating additional operator stress and maintaining position far more accurately and for an unlimited period.

An example of the benefit of using the StationKeep™ mode in a common ROV operation was reported in the following message from the field in 2003:

> "On this job supporting Drilling Operations, station keeping comes in very useful when we start a new well as they drill open hole and the ROV has to monitor the drill shaft and entry to the casing at the seabed for any gas returns, just in case they were to hit a shallow Gas pocket. This is critical as a large amount of Gas could sink the rig. So the ROV is on station for 1-3 days during this operation monitoring the well, this period is called "Spudding In". Visibility can be affected here and station keeping just holds the vehicle in place until it clears up again and you are able to spot the drill bit. When visibility is low you confirm that you are holding location with StationKeep by using the Sonar. So it is used here to keep the ROV close to the drill bit and watch for Gas. It makes it easier on the equipment too, as you are not thrusting all about the place once you loose visibility and try to return to the well. It has the thrusters just ticking over, holding station. As you can see, a drill bit spinning very fast in front of you is a scary thing, tether and ROV killer, so panic can set in if visibility is lost. But with StationKeep, nerves are relaxed, you monitor location with Sonar and don't drift anywhere you don't want to be."

Another common ROV task is pipeline touchdown monitoring (TDM). In this operation, the vehicle provides visual confirmation that the pipeline is being laid in a clear, planned location. In calm conditions with good visibility, this operation is handled easily by most ROV pilots. However, weather conditions can turn a seemingly simple task into a difficult operation. Surface swells can cause the pipeline to surge several meters very quickly in the water column, making it difficult to maintain a visual on the pipeline and stirring up sediment to the point of total visibility loss. In these conditions, the ROV can monitor touchdown using sonar. However, without a clear understanding of the ROV orientation and position relative to the surging pipe, the vehicle can easily move underneath the pipe as it is being laid, trapping the tether. This may not be immediately evident to the ROV crew until several lengths of pipe have been laid, and it is then an expensive operation for the barge to recover pipe to free the vehicle. Surging pipe can also affect the ROV if the pilot does not maintain a safe distance, which can be difficult in low-visibility conditions. StationKeep™, in this case, allows the operator to automatically maintain vehicle position at a safe monitoring distance from the pipe, above the seabed. Both sonar and cameras can then be very accurately focused on the touchdown point, without constant drifting or loss of target. Again, this significantly decreases operator stress and allows the vehicle to perform most of the work with minimal interference.

Another construction-related report from the field highlights the significant benefits offered by the StationKeep™ mode:

> "QUEST 3 recently completed work for [client] on the [project name] project in May aboard the Cal Dive MSV Intrepid. StationKeep was effectively used to perform manipulator-intensive operations on a PLEM [pipeline end manifold] in 3,800 fsw. No ROV manipulator grab points were available on the PLEM, so StationKeep was engaged approximately 1 meter from the valve panel. Manipulator operation included hot stab work and operation of sensitive subsea valves. Valve spacing was tight and the manipulator operator was directed real-time by the client representative to operate a particular valve without touching any other valves. If any adjacent valve was "bumped" it would open and nullify the test. StationKeep provided a stable ROV platform enabling the operator to successfully operate valves and engage hot stabs as directed by the onboard client rep. StationKeep basically enabled critical path operations on the vessel and platform to be successfully completed in real time.
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> "Other examples are similar, where the ROV is directed to monitor or perform intervention on multiple aspects of a job. StationKeep saves the client considerable time as the ROV can simply fly to the location and engage StationKeep. Otherwise, the operator would deploy the 5F [five-function grabber manipulator] and attempt to grab and hold, possibly damaging the subsea device and/or manipulator.
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> "ROVs are often required to fly back and forth rapidly, as in jumper metrology, where the ROV must fly back and forth from the well or manifold to a PLET [pipe line end termination] and either rotate compatts or deploy an ADV [Paroscientific depth sensor in a jig attached to a bottle on the ROV] under a specific amount of time. The time limit is to ensure repeatable readings from the depth sensor. QUEST can complete metrology in record time as she can simply get close, engage StationKeep, and monitor or deploy metrology devices."

The benefits of StationKeep™ thus far discussed have related to tasks where visual references are available. In many instances, such references are not available, making it extremely difficult for pilots to manually maintain vehicle position without a reference point. An example of how StationKeep™ significantly improved the execution of a mid-water operation was reported from the field:

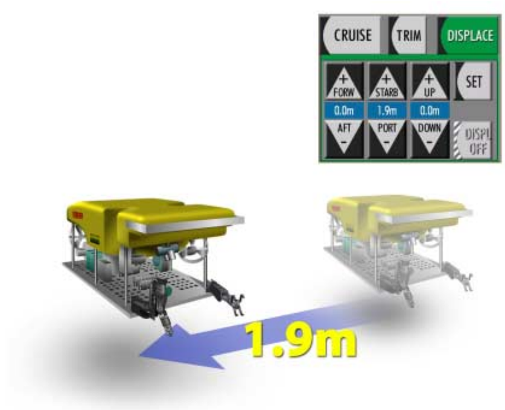
> "Often the task of subsea rigging is performed in mid water with no visual reference. Here StationKeep is utilized to provide the manipulator operator with a stable ROV platform to release the gate on a hook and de-rig and/or conduct general rigging operations which can range from above to complex tasks like manipulating latches on a Del Mar connector."

ENHANCING THE STATIONKEEP™ MODE: AUTOMATIC DISPLACEMENT

In addition to providing the operator with the ability to hold position, the Schilling software team included a StationKeep™ sub-mode called Displacement. This mode builds on the positioning capability of the vehicle by allowing the operators to perform extremely accurate, automatically controlled displacements. The operator can enter a desired displacement in the X, Y, or

Z axes, press a button, and watch as the vehicle control system automatically moves the vehicle in the appropriate direction for the commanded distance, with an accuracy measured in centimeters. Following the displacement, the vehicle reverts to the StationKeep™ mode, holding position until manual control is resumed or another displacement command is given.

Providing operators with this degree of control allows them to perform increasingly delicate and accurate maneuvers with a high degree of reliability and repeatability.



Another message from the field reports:

> "When we are commissioning a well on the seabed, we monitor many valves on a Tree ROV panel while they are operated from the rig close by via the electric/hydraulic umbilical, we flit back and forth around this panel and tree. StationKeep and Displacement help here. You set up in front of the panel and hold station, then displace between the valves they wish to monitor. This, in combination with the QUEST's automatic camera pan and tilt set points, can result in a very efficient and professional operation."

FURTHER ENHANCEMENT

With the successful implementation of the automatic StationKeep™ and Displacement modes, Schilling Robotics has created a base upon which further functionality can be built. Among such features currently in process is an automatic "follow mode" which will allow the ROV to follow a preplanned path using survey data. This function will allow common tasks such as performing pre- or post-lay cable or pipeline surveys to be completed in significantly less time and with improved accuracy.

Using a vehicle-mounted transponder, the loop will also be accurately closed with the position of the vehicle relative to the surface vessel, using seafloor distance and direction traveled in conjunction with GPS information.

The ability to perform typical seafloor measurements will also be provided. In this case, the operator be able to set a start point, accurately displace the vehicle to an end point of a measurement, and record the distance reported from the control system without using sonar targets or other techniques that may introduce inaccuracies or inefficiencies. This function could be used, for example, to measure pipeline free-spans using information reported from the control system on altitude and distance traveled.

SUMMARY

In summary, the use of a DVL to provide the operator with a more intelligent tool for intervention work has been proven to save significant vessel time. It also decreases operator fatigue that results from challenging environmental conditions and from performing tedious tasks that require a high level of accuracy.

The QUEST ROV product line, including the all-electric work class and the ultraheavy-duty hydraulic models will continue to offer DVL-based control, and many other intelligent functions, as standard features.

Acknowledgements

The author would like to thank the following individuals for their input: Chris Legg, Dan Cormany, Greg Engemann, and Richard Gross.