

Advances in ROV Automation

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Introduction

Work class remotely operated vehicles (ROVs) play an increasingly vital and enabling role in today's international deepwater oil and gas exploration and production. Today's deepwater fields can be in water depths in excess of 10,000ft, and the types of equipment being placed on the seafloor are becoming more and more advanced, especially with the advent of subsea boosting and the increasing use of

ations requires experience and hundreds of hours of training.

Today's ROVs incorporate advanced technology, which helps the pilots control the vehicles more precisely and perform tasks more efficiently, than even the vehicles of 10 years ago. The aforementioned increasing demands on ROVs in subsea oil and gas operations will require ROVs to incorporate ever more sophisticated automation.

ROV Automated Control

During the last 10 years, it has become common to find automated control systems on ROVs, providing the ability for these vehicles to be dynamically positioned relative to a subsea structure. This allows the pilot the ability to position the vehicle close to the work site and activate the auto mode, allowing him to operate manipulators or simply to observe while being hands-free. Schilling Robotics, based in Davis, California, was an early pioneer of this technology around 2001, when the company's StationKeep™ capability was introduced on their ROVs. Since that time, the accuracy of StationKeep™ has improved considerably and is unmatched in the industry, with the ability to hold a watch circle with an accuracy of less than 10cm. This is achieved through the use of a Doppler Velocity Log (DVL) and a Motion Reference Unit (MRU), the data from which, when coupled with feedback from thruster sensors, is fed into Schilling's closed-loop control system to give precise control of the ROV.

The common use of these auto-functions has revolutionized the effectiveness of today's ROVs and the pilots that operate them. However, there are limitations when using a DVL to provide dynamic positioning capability. The DVL requires the vehicle to be within 35m of the seafloor since it uses the seafloor as a reference to provide its position data. Outside of the DVL operational envelope, dynamic positioning is unavailable. Also, environmental conditions can affect DVL output, which can cause the dynamic positioning function to disengage and interrupt position control.

One of the industry's desires for many years has been the development of technology that would allow the vehicle to hold position anywhere in the water column. This type of capability would

allow ROV operators to monitor pipelines, platforms, risers, and other structures in mid-water.

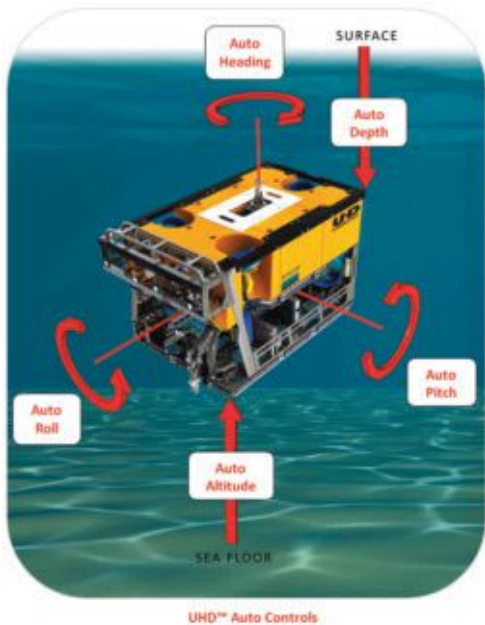
Mid-Water StationKeep™

Over the last two years, Schilling has been developing its Mid-Water StationKeep™ (MWSK™) capability to enhance the operational capabilities of the company's ROVs, the 200hp UltraHeavy-Duty™ (UHD™) ROV and the 150hp Heavy-Duty™ (HD™) ROV.

During March 2011, the company successfully demonstrated the world's first successful application of Mid-Water StationKeep in the Gulf of Mexico, in cooperation with C-Innovation and CDL, following an extensive period of Factory Acceptance Tests.

As described earlier, traditional ROV dynamic positioning functions rely on a DVL system on the ROV that operates within 30m of the seafloor and can only provide relative position. USBL positioning systems provide absolute position, but are unable to support MWSK functionality due to inaccuracy (especially in deep water) and slow update rates, while Inertial Navigation Systems (INS) suffer from drift when unaided.

The solution devised centers around fusing these readily available positioning technologies (INS, USBL, and DVL) and the integration of those technologies with Schilling's next generation closed-loop control system. At the heart of the solution is CDL's MiniPOS3 INS platform, which produces a highly stable INS solution that is aided by either USBL or DVL depending on sensor data availability and quality. The combination of MiniPOS3 functionality and Schilling ROV software automati-



subsea processing. This means that ROVs, and the pilots that operate them, are continuously being called upon to carry out increasingly demanding tasks.

Never was this more evident than during last year's Macondo disaster when up to 16 ROVs were working simultaneously in the attempt to stop the flow of oil. Anyone who witnessed the video footage streaming from these 16 vehicles would have recognized that controlling these vehicles from two miles away is a highly skilled operation. As a result of Macondo, government regulation on subsea operations is increasing the requirements of testing the BOPs during drilling operations. At the same time, there is increasing attention on the maintenance and inspection of these advanced subsea infrastructures. This means that piloting today's ROVs successfully in these types of critical oper-

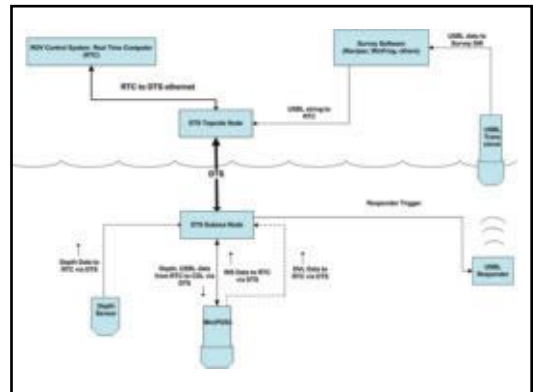


Figure 2 - Architecture and data flow

cally provides the pilot with ROV position information based on the best combination of sensors available.

The architecture and data flow of the complete system is shown in **Figure 2**.

During the sea trials carried out in March 2011 aboard the Chouest Holiday, a C-Innovation-owned UHD™ performed an extensive set of test procedures. This demonstrated the world's first commercial work-class ROV MWSK system utilizing inertial technology aided by a surface based USBL positioning system.

The performance of the MiniPOS3 and the Schilling control system can be seen in **Figure 3** and the results are remarkable. The absolute positioning accuracy of the ROV (without DVL) was noted at a standard deviation of less than 40cm during MWSK. With DVL lock this improved dramatically to approximately 3cm.

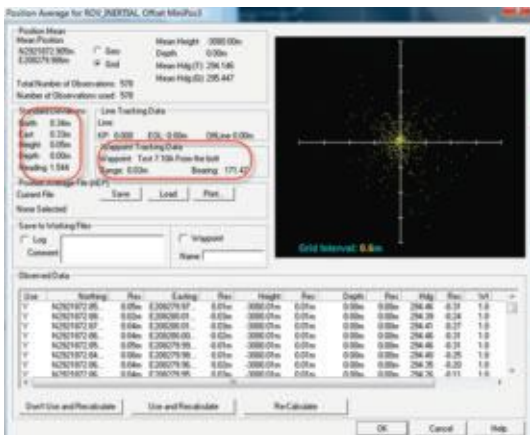


Figure 3 - MWSK trial results

Detailed Results

The trial was very successful with the Mid-Water StationKeep function performing better than expected. MWSK modes, including different sensor aiding states, were tested at a variety of depths.

Data presented below shows five test cases:

- 1) StationKeep with USBL + DVL aiding at 10,000ft
- 2) USBL aiding only at 10,000ft (1)
- 3) USBL aiding only at 10,000ft (2)
- 4) USBL aiding only at 3,000ft
- 5) USBL aiding only at 300ft

These measurements are obtained from MiniPOS3 data, sampled at 10Hz.

In **Figure 4**, the positions of the five test cases shown are aligned at their average positions for ease of comparison. For each case, the data points show the ROVs

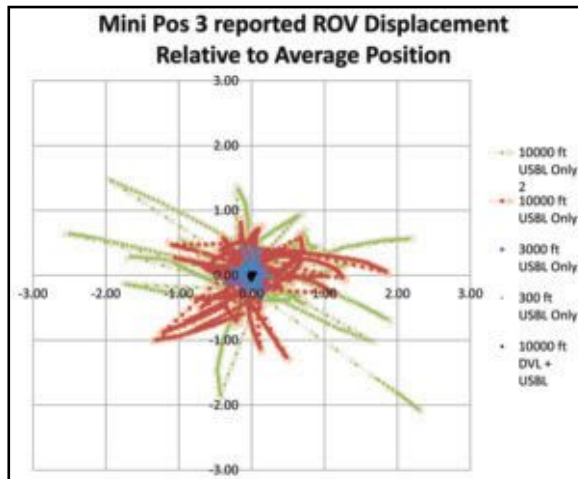


Figure 4 - MWSK displacement results

motion during the test relative to the average position. The arrows between points indicate the relative speed of movement between points. The units are in meters of Northing and Easting. As an example, in the first case of USBL-only aiding at 10,000ft (red data points), the ROV's maximum excursions from its average position was just under 2m in East and just over 1m South.

Figure 5 provides another view of the data. Here, the Y-axis values represent the straight line distance that the ROV moved away from the StationKeep start position

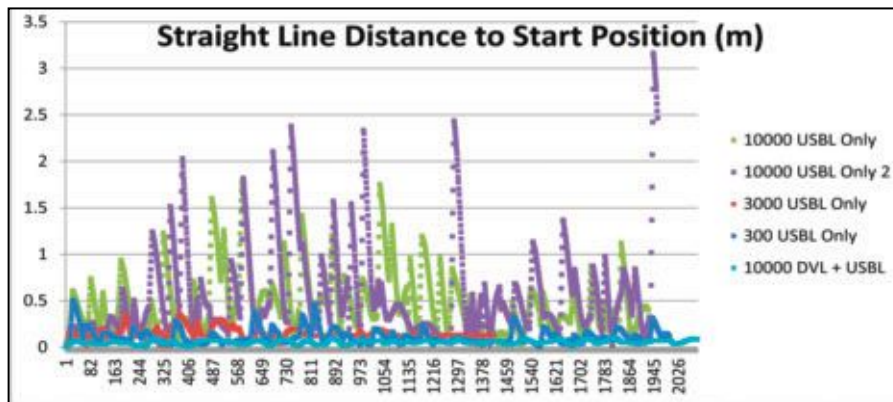


Figure 5 - MWSK straight line distance results

(as opposed to the average position used above) over a 2 to 3 minute period.

As an example, in the second case of USBL only aiding at 10,000ft (purple data points), the ROV moved as far as 3.25m away from its starting position during the test period. We have observed that with USBL aiding only, the ROV was able to keep station within ±0.5m at both ~300ft and ~3,000ft. We also found that the watch circle at 10,000ft was larger and

varied from run to run. Generally, the radius was about 1.5m, but could be as large as 3.25m.

MWSK with USBL aiding is appropriate for a set of tasks that is complementary to tasks that are currently performed with the DVL-aided solution. For example, it would be impractical to operate valves on an ROV intervention panel with a 1.5m to 3m watch circle, but a pilot could hold position during transit with no visual reference, or hold position a safe distance from a subsea structure confidently, without having to use visual or sonar feedback.

It is important to note that although USBL is the only aiding sensor supported today, in principle, other sensors could be used to provide this aiding, including video and sonar. Using these could provide more advanced ROV functions, smaller watch circle, and other capabilities.

As a result of these successful trials, Schilling has already made this technology commercially available. The first application will be installed on a C-Innovation owned UHD™ during July 2011.

Conclusions

ROV auto-functions are now essential to aid the effectiveness of today's advanced ROVs. As oil and gas operations place greater and greater demands on both the vehicles and the pilots that operate them, the level of automation required to operate safely and efficiently will necessarily increase. Schilling's Mid-Water StationKeep technology is the latest in a series of industry pioneering advances that will help ROV operators improve their efficiency, resulting in lower vessel costs.