Improving Remotely Operated Vehicle Positioning

a report by

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Exploration, survey and subsea construction work in deeper water places high requirements on underwater positioning for both dynamic positioning operations and remotely operated vehicle (ROV) positioning. Acoustic positioning systems are continuously improved to meet these requirements. Some systems use the acoustic measurements as position aid for the inertial navigation system (INS) to improve the subsea position accuracy. In this way, an improvement factor of three can be obtained compared with standard acoustic positioning. One example is the Hydroacoustic Aided Inertial Navigation (HAIN) Subsea system.

Over the last years, this system has been used in different kinds of subsea applications, from shallow water surveys to surveys in a water depth of 3,800m, in the North Sea, the Gulf of Mexico and, currently, West Africa. The system is based on technology from the advanced navigation developed in the Hugin autonomous underwater vehicle (AUV) programme.

Acoustic Positioning System

The noise on acoustic positions is dominated by white noise, characterised by relatively high and evenly distributed noise and no drift in the position. There is almost no correlation between the noise on one measurement and the noise on the next measurement, as illustrated in *Figure 1*.

Inertial Navigation System

The noise on an INS without position aid is dominated by coloured noise, that is, a position drift in the position over a given timeframe, as illustrated in *Figure 1*. If inertial navigation is combined with acoustics, this makes a complementary solution. An INS integrates the output of three accelerometers and three gyros contained in the inertial measurement unit (IMU) to compute the position, velocity and attitude.

Each accelerometer measures the acceleration relative to the inertial space. Integration of acceleration gives velocity, and integration of velocity gives position. Each gyro measures the angular rate relative to the inertial space. Integration of angular rate gives roll, pitch and heading.

Position Aid

The aiding position is the position of the ROV in latitude/longitude. When the ROV is positioned with super-short base line (SSBL) from the vessel, the latitude/longitude position is a combination of the acoustic position relative to the vessel and the differential global positioning system (dGPS) position of the vessel. When the ROV is positioned with long base line (LBL), the LBL transponder array must have been calibrated geographically beforehand.

External Measurements

In addition to the accelerometer and gyro readings from the IMU, an INS receives external measurements. For the HAIN Subsea, these are velocity, heading and aiding position in latitude/longitude and depth.

The aiding position calculated by the acoustic system is used both to get an initial value for the position and to limit the drift that is inherent in an INS. The external measurements are used by a Kalman filter to compute corrections of the estimates of the filter. The corrections are weighted according to the expected accuracies of the measurements and to the filter's estimate of its own accuracies.

The ROV On-board System and the HAIN System

The system on board the ROV comprises an IMU, a Doppler velocity log (DVL) for ROV speed, a pressure sensor and a heading sensor.

The HAIN system on board the vessel comprises an operator station, a HAIN computer, HAIN software, vessel position input from dGPS and ROV position input from an acoustic system such as High Precision Acoustic Positioning (HiPAP®). The HAIN system is operated from an acoustic

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Figure 1: Acoustic Used as Position Aid

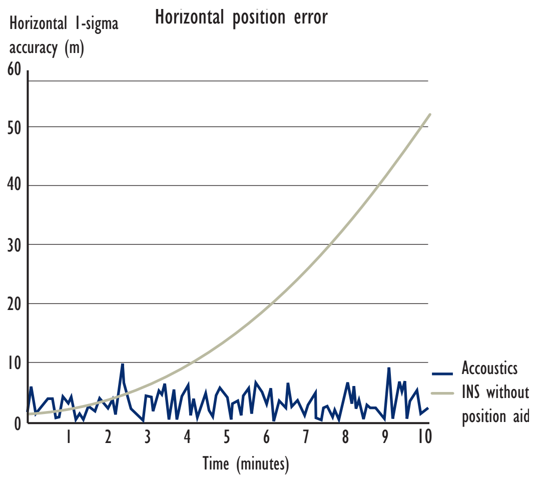


Figure 2: HAIN Subsea Accuracy Figures

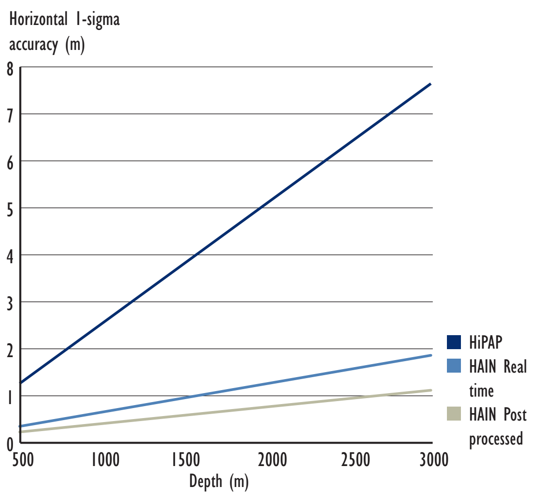
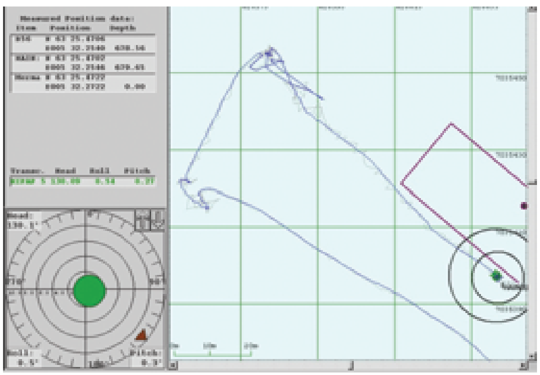


Figure 3: HiPAP/HAIN Screen Dump



positioning operator station. The computer may interface different types of sensors giving these aiding measurements. The computer receives the aiding positions (latitude and longitude) from the acoustic positioning operator station and will limit the position drift inherent in the INS. ROV position, attitude, speed and expected accuracy of the data are sent back to the operator station at an update rate of 1Hz.

Accuracy

The HAIN Subsea accuracy is derived from the combination of acoustic measurements and the readings from inertial sensors on board underwater vehicles in an optimum manner.

The navigation equations updating the vessel position, velocity, attitude and depth are almost continuously based on readings from the IMU. A Kalman filter corrects these values when new acoustic positions and readings are available. The navigation equations updating the ROV position, velocity, heading and attitude are almost continuously based on the readings from the IMU. The Kalman filter corrects these values when new acoustic positions and readings from the other ROV sensors are available.
On the whole, this results in improved subsea position accuracy compared with the acoustic measurements, as illustrated in *Figure 2*.

Post-processing Software

The NavLab post-processing tool reads the files logged by the HAIN computer. When calculating the ROV position, the computer uses measurements both in the past and in the future, giving a better quality than can possibly be achieved in realtime. In this process, NavLab detects wild points in the measurements, which can be excluded from the processing.

NavLab can process with offsets in the sensor readings, and thereby compensate for constant errors in the sensors that were detected after the ROV mission.

Field Results

One screen dump from the HiPAP® operator station is shown in *Figure 3*. Here, the HAIN Subsea system was used for positioning an ROV on a pipeline route survey in the North Sea. The water depth was between 100m and 850m. In this project, the HiPAP SSBL system was used as the acoustic aiding position. When the ROV had finished with a line, it stopped, moved to the next line and then started a new line. The HiPAP measurements were not as stable in the turn as the ROV – probably because of more extensive use of thrusters in the turn.

Conclusion

The many different operational results that have been obtained show that combining acoustic and inertial positioning principles is the ideal solution, because they have complementary qualities. ■