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Underwater Positioning ROV Using Multiple Transducers

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ABSTRACT— This paper introduces the implementation of positioning ROV in underwater navigation solution using multiple transducer technique, which is based on USBL, DGPS, DVL and AHRS measurements. To realize the accurate key element of sub-sea position and frequent update rate of underwater navigation solution, three approaches are chosen. The first one is the underwater positioning system that uses a vessel mounted transceiver to detect the range and bearing to a target using acoustic signals. The second one is Doppler Velocity Log (DVL) that has been used to provide navigation information for ships, Remotely Operated Vehicles (ROVs), Human Occupied Vehicles (HOVs) and Autonomous Underwater Vehicles (AUVs). By using multiple transducers to measure velocity (either bottom tracking or water-column tracking), these observations can be integrated to generate displacements. These relative displacements, when oriented to real-world coordinate systems through heading, pitch and roll sensors can generate absolute displacements relative to geographic coordinate systems. The third one is an Attitude and Heading Reference system (AHRS) that consists of sensors on three axes that provide heading, attitude and yaw information for ROV. They are designed to replace traditional mechanical gyroscopic ROV instruments and provide superior reliability and accuracy, where the global position can be acquired from differential global position to provide improved location accuracy (USBL or DGPS) measurements, considering positioning state machine. Positioning at sea with different approaches can be done by verifying the developed algorithm using the obtained experimental data.

KEYWORDS— ROV, DVL, AHRS

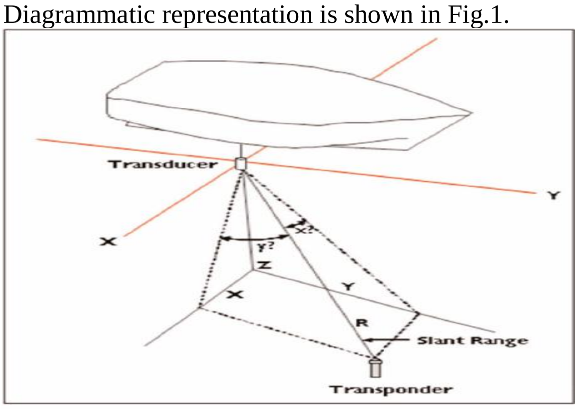
I.INTRODUCTION

Recent advances in system design and sensor performance, together with high accuracy GNSS surface positioning, have led to a significant increase in the capability, performance and accuracy of modern USBL-based acoustic positioning solutions. This has made it possible for such solutions to be used where previously; more time-consuming and expensive solutions would have been employed. At the same time, client expectations and technical specifications have moved forward together with technology and industry experience. High performance vessel USBL systems, operating to a high specification, have become a critical part in meeting the very demanding technical and contractual requirements in modern offshore operations. For example, today it is possible for a properly installed USBL system to achieve positioning accuracy of a few meters at the seabed in water depths of 1000m. In parallel with the development of long range high accuracy USBL systems, similar advances have been made with more portable USBL systems providing reliable tracking in shallow water when working from less sophisticated vessels such as cable lay barges or from small survey vessels. Although the accuracy achieved with portable systems is not as refined, the principles and guidance in this document can be applied equally well to portable systems.

The objectives of this document are to discuss the issues affecting USBL system performance and to describe issues associated with the installation, configuration and documentation of USBL systems on offshore vessels involved in subsea positioning. It is intended for use by offshore construction, survey and inspection companies when chartering third-party vessels with USBL system(s) already installed, when commissioning new USBL installations on new-build or existing vessels, or when maintaining existing systems.

II. USBL ARCHITECTURE

The transducer is commanded to transmit an acoustic signal either hemispherical or within the volume of a fixed cone below the unit. A remote beacon receiving the signal recognizes either the frequency of the signal itself, or a decoded identification tag embedded in the signal, and replies to the transmission. The USBL system makes a precise observation of the time difference between transmission and reception of the signal at the transducer. If the speed of sound is known together with the turnaround time of the signal in the beacon, then the distance to the beacon can be calculated. By observing the phase change of the return signal as it passes across the different receive elements in the transducer, the relative horizontal and vertical angles between the transducer and the remote beacon can also be determined. Thus, the USBL system is essentially a three dimensional range and bearing system and it is important to recognize that, as such, there is no ‘third line of position’ to provide quality control of the calculated position solution. That is, if the range and/or the bearing contain gross or systematic error, there is no other physical observation in the system to highlight a possible position error. In order to ensure that the system computed position is not erroneous, the USBL system should perform to a given specification and the operators should be competent to operate the equipment correctly. Diagrammatic representation is shown in Fig.1.



$$X = R \cdot \sin \theta x$$
$$Y = R \cdot \sin \theta y$$
$$Z = R\ (1 - \sin 2\ \theta y - \sin 2\ \theta x)\ 1/2$$

Fig 1. Functioning of USBL System

The observation cycle will repeat on receipt of the return acoustic signal, or following a timeout period if no return acoustic signal is received. Although some systems use ‘ping stacking’ techniques to mitigate against position update rates decreasing, typically the positioning cycle will increase with water depth and the number of acoustic beacons being tracked. The accuracy of the position solution will also decrease with depth (and range at a given depth) due to the propagating impact of the errors in the range and angle observations.

The observed range and angle data are applied to the real time vessel transducer position to produce a calculated relative position for the beacon. This may be undertaken in the USBL system itself (particularly where position output to a vessel’s DP system is required) and/or remotely in software in the online survey computer. The USBL system is configured to output a raw data telegram to the survey computer, typically at the instant an enabled beacon reply is detected and processed, and this contains the raw relative XYZ distances between the remote transponder and either the USBL transducer itself or the vessel CoG or CRP, depending on the physical offsets entered into the USBL system itself.

III. SENSOR SYSTEM

A. Heading Reference System (HRS)

Ideally one or more heading reference system should be interfaced directly to the USBL system. Whilst the survey position is typically computed in the online survey computer, the use of a heading reference system within the USBL system aids the acoustic observations and allows absolute computation internally that may be used for DP purposes. The heading reference system may be either a gyrocompass or it may be based on dual GNSS antenna carrier phase observations. The following heading reference system issues should be considered:

The manufacturer quoted accuracy, particularly for an HRS interfaced to the online survey computer, should ideally be better than 0.2º x secant latitude

- Consideration should be made for updating of speed and latitude input as necessary.
- The HRS should be regularly calibrated on-site by the vessel’s surveyors, by comparison with a known baseline, higher order system or astronomical observations. The computed correction (computed minus observed, C-O) should be entered into the USBL topside system and/or the survey positioning software.
- In some cases, as with GNSS derived heading reference systems, the C-O may be applied within the HRS itself.

Care should be taken to ensure the correction is not applied twice.

B. Motion Reference Unit (MRU)

Ideally one or more MRU should be interfaced directly to the USBL system. The performance and reliability of the real time pitch and roll observations to the system are of crucial importance. The following motion reference unit issues should be considered:

- The manufacturer quoted dynamic (not static) accuracy should ideally be better than 0.025º in pitch and roll.

- Ideally the MRU should be installed close to the vessel CoG. The MRU should be aligned parallel to the centre line of the vessel, the right way up, with the forward indicator mark or arrow in the direction of the bow.
- The MRU should be configured for minimum latency of data output.
- The MRU should be fully calibrated at initial installation through comparison with a higher order system or through dimensional control observations. The computed pitch and roll corrections (C-O) should be entered into the MRU system at source such that all the interfaced MRUs are aligned and output the same data. Where this is not practical, it should be possible for the USBL operator station to apply relevant C-Os to received MRU data prior to the data being used within the position calculation. In this way, overall USBL calibration results observed and used by the surveyors remain consistent throughout primary/secondary MRU change-outs at the operator station. Assessment of MRU performance at source over time consists of validation using land survey techniques to calculate vessel attitude whilst the vessel is alongside or in dry dock, and comparison of this data with the MRU observations. Any anomalies arising should be reported and investigated.

- The pitch and roll sign convention of the MRU data output should be clearly documented within the installation report and shown to be appropriately addressed within the USBL system configuration.
- The digital output rate of the MRU to the USBL system should be configured to the maximum possible.
- Compliant with both systems, and as a minimum 10Hz. The real-time data output should have negligible latency, or at least the minimum configurable latency.

C. Surface Positioning System

Ideally, surface positioning systems of the highest order of accuracy should be interfaced to the USBL system. This will assist in providing optimal calibration of the system and positioning for DP operations and in providing a comparative dataset when resolving USBL based problems. The following surface positioning system issues should be considered:
Systems should be of high accuracy (e.g. ideally better than ±0.2m);

- The DGNSS system should be installed, operated and maintained in compliance with manufacturer and IMCA guidelines.
- The digital output rate of the GNSS system to the USBL system should be configured to the maximum possible compliant with both systems, ideally a minimum of 1Hz.

The GNSS system should be able to supply the preferable/optional timing information (ZDA and 1PPS) as well as position. The physical offsets between GNSS antennas, USBL transducer and the vessel common reference points should be accurately measured documented and entered into the USBL topside system.

D. Sound Velocity Profiler (SVP)

As one of the two primary calculations of a USBL system is distance, determined through observation of travel time, an accurate knowledge of the speed of sound profile along the signal path is critical. The sound velocity (SV) profile through the water column is observed at regular intervals using a sound velocity profiler, which works by timing the two-way travel time of the acoustic signal between the transducer and reflector, or is calculated from observations of salinity, temperature and depth. Typically SV profiles are observed and recorded prior to system calibration and subsequently onsite at intervals determined by the observed variation in the sound velocity profile.

IV. SIMULATION AND PERFORMANCE TEST

E. Simulation

For the performance test of the AHRS algorithm, simulink in Matlab has been used. As an input value for the simulation program, 10N of the x, y, and z axes and force as well as the moment force which has a sine wave form with 0.69Nm toward the x- axis, 0.66Nm toward the y-axis, and 0.36 Nm toward the z- axis were used. For angular velocity, acceleration, and the geomagnetism sensor, a modeled sensor of which the average noise level was 0 and the variance was 2.54E-4, 8.0E1 was used. Fig. 2 shows simulation results where the top graph represents the estimate value using EKF, and the middle graph indicates the actual value. The lowest graph shows the simultaneous expression of estimates and actual values. As shown in the third graph, the estimated value using EKF is quite close to the actual values.

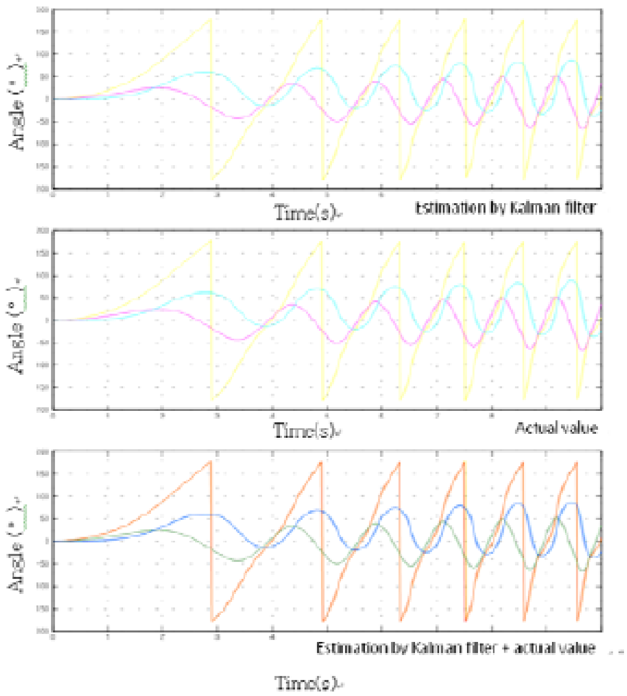


Fig. 2. Simulation results

F. Test Result

For the implementation of the initial alignment and AHRS algorithm to the actual USV, a hardware system using a DSP28335 microprocessor and an ADIS16405 IMU sensor was constituted. Here, DSP28335 has a 150MHz speed and a floating point calculation performance. The signal processing sensed from the IMU sensor was estimated in real time.

V.CONCLUSION

For the motion estimation of the AUV, an initial alignment method has been designed in which the 3- axis acceleration and geomagnetism information of an IMU sensor were used and the motion has been estimated by the construction of an AHRS after fusing 3-axis angular velocity, acceleration, and geomagnetism data. For the performance test of the motion estimation in AHRS for the AUV, a test apparatus has been constructed using ADIS16405, which is an IMU sensor and DSP28335, on which the signal processing algorithm and an EKF algorithm were transplanted and its performance was tested. According to the test, the estimates of the roll angle has an error range of 0.22°, the estimates of the pitch angle have an error range of 0.24°, and the estimates of the yaw angle have an error range of 0.21°. This means that the output angles of the roll, pitch, and yaw in the developed AHRS have less angle errors than the 3-axis angular velocity noise of the specified ADIS16405 IMU sensor.

REFERENCES

[1] Milne, P. H., Underwater acoustic positioning systems, Gulf Publishing Company, (1983).
[2] Woolven, S. and Field, M., *POS/SV – an aided intertial navigation system for submersible vehicles*, Proc. Of Oceans '98 Conference, Vol. 1, (1998) pp. 103~107,
[3] Yun, X., Bachmann, E. R., McGhee, R.B., Whalen R. H., Roberts, R. L., Knapp R. G., Healey, A. J. and Zyda, M. J., *Testing andevaluation of an intergrated GPS/INS system for small AUV navigation*, IEEE J. of Oceanic Engineering, Vol. 24, No.3, (1999) pp. 396~404.
[4] An, P. E., Healey, A. J., Smith, S. M. and Dunn, S.E., *New experimental results on GPS/INS navigation for Ocean Voyager 2 AUV*, Proceedings of AUV '96, 1996 pp. 249~255.
[5] Marco, D. B. and Healey, A. J., *Command, control, and navigation experimental results with the NPS ARIES AUV*, IEEE j. of Oceanic Engineering, Vol. 26 No. 4, (2001) pp. 466~476.
[6] Ppoulis, Probability, Random Variables and Stochastic Process, Mc-Graw Hill.
[7] Maybeck, Peter S., *Stochastic Models, Estimation, and Control*, Vol.1.
[8] Alberto Leon-Garcia, Probability and Random Process for Electrical.
[9] Patrick Billingsley, Probability and Measure, Ed. Wiley, (1979).