Enhanced Subsea Acoustically Aided Inertial Navigation

This thesis deals with enhancing state-of-the-art underwater acoustic–inertial navigation systems that are necessary for deep water robotic operations. Throughout the project intelligent and simple operational solutions to complex real-world problems was emphasized.

Offshore hydrocarbon, oil and gas, exploration is advancing further into treacherous territories such as deeper waters and arctic region. Deep underwater navigation poses a deluge of challenges; there is no such luxury as Global Navigation Satellite Systems (GNSS) underwater. Many of these challenges have been solved, but vessel time is expensive so lots of effort is put into cutting down on time spent on all tasks. Accuracy demanding tasks such as subsea construction and surveying are subject to strict quality control requirements taking up a lot of time. Offshore equipment is rugged and sturdy as the environmental conditions are harsh, likewise should the use of it be simple and robust to ensure that it actually works.

The contributions of this thesis are all focused on enhancing accuracy and time efficiency while bearing operational reliability and complexity strongly in mind. The basis of inertial navigation, the inertial sensors are treated in a calibration study with three scenarios: factory, in-field and at-sea calibration. Factory calibration compensates for sensor misalignments during the manufacturing process and for intrinsic sensor biases etc. For calibration a precise two-axis turn-table is required. It is shown that long-term effects on inertial sensors can be calibrated and assessed in-field, on land without specialized equipment, or at sea with certain realistic limitations and assumptions.

Automatic calibration of complex multi-sensor acoustic-inertial navigation systems, using parameter estimation, is employed on unprecedented high dynamic trajectories collected from sea-trials. These are needed to increase navigation accuracy to the cm-level and beyond. The same techniques can also be used for regular navigation in order to minimize both time and human error in parameter measurements.

In a unifying litmus test, the entire body of work is applied in a novel and potentially revolutionary methodology for the most challenging of all subsea survey and construction tasks: spool piece and jumper metrology. Two distinct approaches are investigated: One seeks to eliminate acoustic seabed transponders, but keep transponders at desired survey points; the other uses a mapping sensor such as subsea lidar to simply map the area in question. Both approaches are shown to work in practice. Generating high resolution maps, as the latter approach, is how the author anticipates all subsea surveys will be conducted in the near future.

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