A new non-linear algorithm for complete pre-flight calibration of magnetometers in the geomagnetic field domain

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Abstract: A new algorithm for complete pre-flight calibration of triple magnetometers is developed. The traditional approach for calibrating these sensors are based on a cumbersome procedure called 'swing' that involves levelling and rotating the vehicle containing the magnetometers through a series of known headings. Application of such a procedure is difficult and costly. Recently, new approaches have been developed to calibrate magnetometers without the need of attitude information. Such methods are used mostly for the calibration of biases and scale factors. Additionally in situations where misalignment errors are also to be estimated, they are usually modelled as errors of a non-orthogonal frame relative to an orthogonal frame creating six additional unknown parameters to be estimated. The presented approach in this article utilizes a three-step algorithm to fully calibrate triple magnetometers without the need of attitude information through a batch least-square non-linear estimator. Since misalignment parameters are not all identifiable through attitude-independent techniques, the measurement equation is initially factorized such that the non-observable parameters are removed. This would allow identification of three parameters through attitude-independent techniques, while identification of the other three that require horizon information is carried out using a secondary procedure. In step one of the proposed scheme, the non-linear observation equation is transformed, via two non-linear functions, to a linear space with respect to the unknown parameters and the new unknown parameters are estimated with batch least-square estimator. In the second step, the first non-linear function is solved for nine parameters that have non-linear relationships with respect to the desired biases, scale factors, and misalignments. Subsequently, the second non-linear function is solved giving the main unknown calibration parameters in a non-physical frame. Finally, in the third step, to find the required transformation matrix between the magnetometer platform frame, the magnetometer is rotated in a horizontal plane about x, y, and z platform axis, respectively. Assuming that the vertical component of the geomagnetic field is known, the calibration parameters are next determined with respect to the platform frame utilizing the rotation matrix. The proposed three-step algorithm does not need any initial condition or iterations for convergence and more importantly does not require any attitude information for the estimation of misalignments. The algorithm is simulated to validate the performance of the estimator using experimental data gathered from a magnetometer triad. Results show relative superiority when compared with those of the two-step algorithm with heading errors of the order of 0.5 to 1 degrees.

Author Keywords: Magnetometer calibration; Non-linear estimator; Three-step algorithm; Two-step algorithm

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