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Book Review

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Strapdown Inertial Navigation Technology

D. H. Titterton and J. L. Weston, Peter Peregrinus, Piscataway, NJ, 1997, 455 pp., $98.00, ISBN 0-86341-260-2

Navigation is the use of basic geometric principles and measurements in position, velocity, and acceleration to determine the navigator's position, velocity, and attitude (navigation state) and predict (using the known dynamics of the navigator's vehicle) the track and arrival time of the vehicle at a way-point or destination.[1–3] Early inertial navigation systems had their sensors (rate gyros and accelerometers) mounted to a gyro-stabilized platform mechanically isolated from the rotational motion of the vehicle. Modern systems have removed most of the mechanical complexity of platform systems by having the sensors attached rigidly, or strapped down, to the body of the host vehicle. Inertial navigation is a recent development, dependent upon innovations in gyroscopes and angular rate sensing, accelerometers, stellar trackers, and information processing with Kalman filters and flight computers. Milestones in this continuing development have occurred as a result of the development of the miniature rate-integrating gyroscope, the dynamically tuned gyroscope, ring laser and fiber optic rate sensors, and vibratory gyroscopes. Although basic principles of inertial navigation do not change from one application to the next, the accuracy of the inertial sensors and the precision limits of the computations vary dramatically. The instrument technologies and the implementation techniques also vary.

This book provides insight into methods and technologies applicable to several types of inertial navigation. It contains excellent reviews of gyroscope, accelerometer, and multisensor technology as well as models, including typical performance parameters for gyroscopes and accelerometers. The sections on system alignment and calibration contain most, or all, of the commonly used parameters and dynamic/kinematic models for the systems. The performance of early ships inertial navigation systems (SINS) was modeled with few parameters—at most a dozen or so. More modern SINS with much tighter performance requirements require some 150–200 parameters, with the system dynamics included in a Kalman filter with 150–200 state variables. The models included in this book are low level, but the provided outline of a Kalman filter implementation can be extended to higher-order models including platform flexures, thermal distortions, and more complex sensor dynamics.

The thirteen chapters and two appendices of this book provide a well-reasoned introduction to inertial navigation in general and strapdown methods in particular. Chapter 3, "Basic Principles of Strapdown Inertial Navigation Systems," provides a robust introduction to the mechanisms of these systems, including coordinate frames, attitude representations in terms of direction cosines, Euler angles, and quaternions. Chapters 4 and 5 introduce mechanical gyroscopes, as well as various vibrating technologies and optical sensors, principally ring laser, fiber optic, and ring resonator gyroscopes. Chapter 6 covers a wide variety of accelerometer types. Chapter 7 is a thorough treatment of testing, calibration, and compensation. Chapter 8 covers sensor configurations for strapdown systems, as well as computing requirements, power, and vibration isolation. Chapter 9 covers techniques for system alignment on the ground, in flight, and at sea. Chapters 10, 11, and 12 cover basic computations, performance analysis, and integrated systems, which are inertial systems aided by external position fixes and velocity measurements. Chapter 13 is a well-constructed design example, including system requirements, choice of mechanization, error budget calculations, computing requirements, and performance enhancement by the use of external position, velocity, and heading measurements. There is a small section on the use of global positioning systems and another on star trackers.

The book provides a well-rounded introduction to inertial navigation techniques with a catalogue of sensors, their error models, and their integration into navigation systems. A more complete treatment would improve the sections on the Kalman filter,[4] and a section or chapter on covariance analysis modeling to accompany Chapters 12 and 13 would be useful. However, the book is a welcome addition to the textbook literature and does much to replace classic books that are out of print.[1,2]

References

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[4]Gelb, A. (ed.), *Applied Optimal Estimation*, MIT Press, Cambridge, MA, 1974.

Donald L. Mackison
University of Colorado