Book Review

Principles of GNSS, Inertial, and Multisensor Integrated Navigation Systems – Second Edition

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The preface to this book states that it is intended for use by professional engineers and scientists in industry, academia, and government; and by students, mainly at the MSc and PhD levels. The book's main aims are:

- To describe, both qualitatively and mathematically, global navigation satellite systems (GNSS), inertial navigation, and many other navigation and positioning technologies, focusing on their principles of operation, their performance characteristics, and how they may be integrated together;
- To provide a clear and accessible introduction to navigation systems suitable for those with no prior knowledge;
- To review the state of the art in navigation and positioning, introducing new ideas, as well as presenting established technology.

With these very clear aims, the author has produced an outstanding reference work for all those concerned with the science of navigation systems. He offers a comprehensive introduction to the design and operation of the sensors involved and an in-depth treatment of possible architectures for component integration.

This second edition is a major upgrade of the version first published at the end of 2007. The main additions include five new chapters and substantial revisions of three others, while the remaining ten have all been expanded and brought up to date. The other major addition is the inclusion of a DVD, which is almost a book (or a Volume 2) in its own right; it includes: eleven appendices, worked examples in Microsoft Excel format, problems and exercises including solutions, and some Matlab INS/GNSS simulation software. For those who are familiar with the first edition, the DVD also contains a summary of the changes made and a link to a website for the book, where the author maintains a list of updates of information that becomes out of date (particularly important in the field of GNSS where changes are occurring

almost daily), corrections of any reported errors and other important notes and references; he offered a similar service for the first edition.

Chapter 1 of eighteen chapters provides an overview of the fundamental aspects of navigation and the technology of navigation systems. Chapter 2 introduces the mathematics of coordinate frames, frame transformations and Earth models so vital to the design of any navigation system. Chapter 3 introduces the Kalman filter and its use in the integration of navigation sensors. Chapter 4 describes the principles of inertial sensors and the characteristics and the propagation of their errors, while Chapter 5 details how these components are used to build a variety of inertial navigation solutions. Chapter 6 considers other dead reckoning methods as well as some methods of measuring attitude, height and depth.

Chapter 7 explains the physical principles of radio positioning and the error sources involved. The next three chapters deal with global navigation satellite systems (GNSS). Chapter 8 introduces the fundamental concepts including: the architecture, signals and orbits used, and a brief description of GNSS both in service and proposed. Chapter 9 discusses the hardware aspects of user equipment and the methods used to derive position, while Chapter 10 deals with more advanced techniques to improve accuracy and reliability. The next two chapters cover other radio positioning systems; long and medium range systems such as Loran and DME are described in Chapter 11; short-range systems such as pseudolites and underwater acoustic systems are covered in Chapter 12. Finally, before discussing the design of integrated navigation systems in detail, Chapter 13 provides an introduction to map matching and terrain-referenced navigation and other environmental feature matching techniques.

Chapters 14 to 17 on INS/GNSS integration, INS alignment, multi-sensor integration and integrity monitoring are probably the most important chapters of the book. The first includes detailed descriptions of loosely, tightly and deeply coupled integration, while Chapter 15 looks at the problems of INS alignment within integrated navigation systems. A more general discussion about the integration of other sensors is provided in Chapter 16, and Chapter 17 deals with fault detection and integrity monitoring. Finally, the last chapter discusses applications within the various domains and looks ahead to possible trends.

The Contents section is very detailed and well supported by a reasonably detailed Index. Each chapter commences with a clear explanation of what it covers and is excellently supported by references from learned journals and books at the end. Having been published in the USA, it is not surprising that the spellings of some words are in English (US), but the style is very clear and easily understood so these have no effect on a reader's understanding. Clearly, the book has been written with the expertise and dedication of a very experienced research scientist and academic; it is not the type of book to be read cover-to-cover, and the mathematics involved are not for the faint-hearted. There is some repetition between chapters but, as the book will probably be used mainly as a reference text, this helps a reader by avoiding excessive cross-referencing to other sections.

One criticism I have on content is that the author dismisses air data (Indicated Air Speed and Mach No.) at 6.6.2 as of little use to navigation. As a professional navigator, I have to point out that IAS is extremely important to navigation and aircraft performance in a number of areas. For example, in the past, a navigator used the back of a Dalton computer to calculate True Air Speed (TAS) from IAS, outside air temperature and altitude and so calculate wind velocity using values of heading, track and groundspeed. Manual calculation has since been replaced by air data computers to input TAS and enable navigation systems such as flight management computers to complete the same operation. In fact, while Required Navigation Performance gets a mention in a couple of places, flight management computers which are so vital to ICAO's aims for Performance-based Navigation do not.

These criticisms aside, this book is a very important and valuable reference text on navigation system technology with an emphasis on integration; I recommend it as essential reading, particularly for students.