Preface

The main aims of this book are as follows:

- 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.

This book is aimed at professional engineers and scientists in industry, academia, and government; and at students, mainly at the master's and Ph.D. levels. This book covers navigation of air, land, sea, underwater, and space vehicles, both piloted and autonomous, together with pedestrian navigation. It is also relevant to other positioning applications, including mobile mapping, machine control, and vehicle testing.

This book begins with a basic introduction to the main principles of navigation and a summary of the different technologies. This is followed by a mathematical grounding in coordinate frames, attitude representations, multiframe kinematics, Earth modeling, and Kalman filter-based estimation. The different navigation and positioning technologies are then described. For each topic, the basic principles are explained before going into detail. The book goes beyond GNSS and inertial navigation to describe terrestrial radio navigation, short-range positioning, environmental feature matching, and dead reckoning techniques, such as odometry, pedestrian dead reckoning (PDR), and Doppler radar/sonar. The Global Positioning System (GPS) and the other GNSS systems are described together. The final chapters describe inertial navigation system (INS)/GNSS and multisensory integration; INS alignment, zero updates, and motion constraints; fault detection, integrity monitoring, and testing; and navigation applications.

The emphasis throughout is on providing an understanding of how navigation systems work, rather than on engineering details. This book focuses on the physical principles on which navigation systems are based, how they generate a navigation solution, how they may be combined, the origins of the error sources, and their mitigation. Later chapters build on material covered in earlier chapters, with comprehensive cross-referencing.

The second edition is more than 50% larger than the first, providing the opportunity to devote more space to the underlying principles and explore more topics in

detail. Eight chapters are new or substantially rewritten, and the remaining chapters have all been revised and expanded. Subjects covered in more depth include map matching, image-based navigation, attitude determination, deeply coupled INS/GNSS integration, acoustic positioning, PDR, GNSS operation in poor reception environments, and a number of terrestrial and short-range radio positioning techniques, including ultrawideband (UWB) positioning. New topics include the unscented Kalman filter and particle filter, GNSS shadow matching, motion constraints, context, cooperation/collaboration, partial inertial measurement units (IMUs), system design, and testing.

An accompanying CD has also been introduced. This CD contains worked examples (in a Microsoft Excel format), problems, and MATLAB software, as well as eleven appendices containing additional material.