Preface

Today, robots face a similar challenge to what occurred to many members of human societies of the First World in the last century: they are trying to make their way out from a profitable and well-known position in the industry—mainly as robotic manipulators—to land into a much more unpredictable and undefined place in the service sector where they will have to work side by side with humans; from taking the role of humans at work to live *with* humans all the time; from the nuts and bolts of mechanics to the more ethereal challenges of understanding their place in our world. Mobile robots have left behind their cousins, the manipulator arms, along this way, for our world is much more dynamic, large, and complex than anything a fixed arm could handle.

From the first prototypes resembling home appliances in the 1960s to the present commercially-available humanoids that seem to have jumped out from a *manga* TV series, mobile robots have struggled to freely move among us efficiently and safely. When we look at them today, it is not difficult to imagine how they would interact with people if they had only part of the capabilities claimed by their manufacturing companies, in how many applications they might be employed, and in all the ways they could help us in our daily lives.

The general public would probably be surprised by the actual limitations of these robots. Amazing as they look (and as they truly are, from a scientific perspective), we would do better in remembering that it was only during the last two decades that robots were endowed with the first consistent and successful theory of localization and mapping, which are the two basic operations that underlie any task we could devise for any practical robot: knowing *where it is* within its environment and figuring out what *that environment looks like*. Today, these two fundamental problems cannot be considered to be completely solved for every practical situation yet, in spite of the remarkable scientific corpus developed around them. This book aims at introducing that corpus to the reader. More concretely, we focus on mobile robot localization and mapping approaches that rely on the theory of probability and statistics.

The theory involved in probabilistic localization and mapping methods can become quite cumbersome, in accordance with the importance and quality of the obtained results. Books and papers exploring those complexities are easy to find, but they may be difficult to grasp for those who are not active researchers in the area and do not have a solid background in mathematics. Furthermore, most of the material is quite scattered among journals, books, and conference papers, and in many occasions is addressed from the diverse—and often confusing—terminologies of very different disciplines. Since mobile robots have begun to get out of research labs and into the hands of the general public, we believe it is now time to offer a comprehensive introduction to these subjects that is appropriate for a wider audience than traditional scientific literature, and that gathers in a single place the fundamental concepts needed for fully understanding the problems, whatever area of science they come from.

From the perspective of two authors with many years of experience researching and teaching in this field, we have aimed this goal in the gentlest possible way, while still doing it rigorously. In particular, we have focused on three aspects: firstly, on explaining and justifying most deductions that are involved in the relevant parts of the theory, including step-by-step demonstrations that are typically obviated in specialized literature; secondly, on including the probabilistic, statistical, and robotic bases that other texts take for granted—even after saying otherwise; and thirdly, on providing a glimpse of the historical development of the covered theories and methods, not intending to offer an exhaustive historical timeline but a sufficient background. Our purpose is that the interested reader can really understand the treated issues in scope and depth, instead of just presenting powerful and sophisticated mathematical tools with obscure inner workings.

The book has been designed to be useful for practitioners, graduate and postgraduate students, and researchers mostly interested in a reference guide. No previous knowledge on probability and statistics is required—although it would speed up the reading, since two entire chapters are devoted to providing that background! Also, the prerequisites in physics, calculus, and algebra have been kept to the necessary minimum; alas, self-containment is just an ideal in any finite work these days. Thus, we have had to assume that the reader has the most elemental knowledge of those three disciplines—we provide, in Appendix E, some reinforcement on concepts that are especially important for the understanding of the problems.

This book is structured in three sections. The one that possibly makes this text more distinctive in its kind is section 1, which collects for the reader the robotic, probabilistic, and statistical backgrounds required for a good comprehension of the rest. Sections 2 and 3 follow the logical development of the main problems addressed in the book: localization and mapping, respectively. This organization is intended for both a sequential reading and for an easy selection of material for reference or teaching.

The first idea about writing this book came from the class notes by the first author for a postgraduate course on mobile robotics. Their main contents, and therefore a substantial number of concepts and explanations currently in the book, have been used for that purpose during several years; they should also be amenable for teaching in more introductory courses. In this use, a professor could choose to drop the first part if the mathematical background is assumed for the students, something that will depend on the academic context of the subject. The book also introduces some advanced issues in Simultaneous Localization And Mapping (SLAM) and many recent developments, mainly coming from the experience and continuous work of the second author during his PhD thesis and beyond.

Overall, we expect our book to serve as the starting point of a fascinating journey into this field, by setting the foundations of further detailed and thorough studies. Working in probabilistic robotics can certainly be tough, but we can assure you—this much we know—that it can be highly rewarding too. Our ultimate hope is that this text provides you with most of the tools needed to open a well-marked track into the jungle of probabilistic localization and mapping.

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April 2012