Book Review

Sensors for Mobile Robots: Theory and Application—H. R. Everett

Reviewed by Aarne Halme

I. ABOUT THE TOPIC AND THE AUTHOR

There are many books on robotics but very few of them treat specifically mobile robots. First of all, it is more than welcome to see that kind of book and the readers like me, who have worked in this area it contains. Then sensors—the author has really taken the bull by the horns! It is a well-known fact that mobile robots are complex intelligent systems with many subsystems for locomotion, navigation, piloting, motion planning, perception, etc. Someone can say that this is an old-fashioned way to list them—they are all parts of the same behavioral system—but, nevertheless, perceptions always exist. And it is of crucial importance. No doubt sensors make up the most difficult problem area in this field. In almost all real applications—perhaps some standard AGVs excluded—the scenarios of mobile robots include many uncertainties related to the environment, position information and execution of the task itself. Thus they cannot be programmed off-line so easily and completely as the traditional industrial robot arms. Programming and control must essentially rely on the information provided by sensors and it is not possible to compensate the lack of this information by computer intelligence, although many people tend to believe so. What is important to note is that sensors are based on physics (in some cases on chemistry or even biology) and many of the problems encountered in this field are basically problems of physics. If one likes to take one point up from the book to be mentioned above all others, in my mind it is that the author has understood this fact very well. The way in which the book has been written taking into account and explaining the physical background of different types of sensors, is really marvellous. The author, H. R. Everett, has clearly a very good background for writing this book. Since the mid-1960's, from his high school times, he has worked with mobile robots, in the course of his studies and later on in his professional life and—what is noteworthy—it looks as it has been his hobby, too. He has by himself built several mobile robots which he describes in a personal and lively way, and which are also used as case examples. The ability to understand the problems in detail, which is one of the great merits of the book, is clearly result of this personal interest in the subject.

II. WHAT DOES THE BOOK CONTAIN?

Sensors for mobile robots can be understood in a strict sense to include only the devices that provide information about the inside state and outside environment of the robot, or in a broader sense also devices for navigation, i.e., for localising the robot in a certain coordinate system and for finding its way from one point to another. The author has taken the subject in the broad sense and in fact quite a big part of the book deals with navigation sensors. On the other hand, machine vision and image processing systems have not been included

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in the book as a topic, instead optical sensors and related technology play an important role. This is a sensible choice, because machine vision is an extensive area in itself and there are many books on it already.

The book starts with an introduction where the author introduces a number of mobile robots, of which some he has developed by himself, others he knows well via their development project. Most of them are related to military or security type of applications, including both fully autonomous and teleoperated robots. The field of application is thus restricted, but it includes robots designed for both interior and exterior use with quite versatile scenarios. A point that could be noted, however, is that none of the robots has a manipulator or a tool to work with (some examples of such robots are, however, shortly described later in the book). This defect may have influenced the content in such a way that only sensors specifically related to mobility are included. Thus odometry sensors are included, but sensors needed for example for manipulator or tool control, as those for force, attitude, or acceleration sensing have not been included. Regardless of this, presentation of other fields of applications, like worksites (construction, mining, agriculture...), services, undersea or space could have given a wider understanding of the needs for sensors. Nevertheless, the collection of sensors presented is respectable and covers the essential need for mobile robots.

The author presents the material in a nice and logical way by taking the main functioning principle of sensors as the leading argument. Sensors using different physical phenomena, like ultrasound, light or electromagnetism are then presented as different types of solutions to the (almost) same problem. Each chapter also includes an introduction to the background or physics of the phenomena utilized in the sensor construction, and several examples of real—in many cases, commercial— applications. The presentation starts with dead reckoning sensors where mainly the distance measurement odometer sensors are treated. Heading measurement devices, like compasses or gyros, are considered later on. Everybody with experience on constructing a mobile robot knows that odometry may be quite a tricky thing to implement. The author also analyzes different mobility configurations carefully and shows the tricky points in wheeled locomotion systems.

The next item is *tactile and proximity sensing*, which the author covers well by introducing practically all contacting and non-contacting principles in use. Especially the new sensors, like optical, microwave-based or magnetostrictive are explained and covered well. The next item is *ranging sensors* which are treated separately in four chapters introducing the *triangulation, time-of-flight, phase-shift* and other principles (like interferometry), respectively. All the useful physical media optics, ultrasonic and millimeter waves are included. This is one of the highlights of the book and is really nice to read. The author has indepth knowledge of the topic and he introduces many such sensor constructions that are not familiar even to the people working in the field. As a tutorial, but anyway as an important and relevant part of the book, the author summarizes in two chapters the main characteristics of acoustical and electromagnetic energy. The idea is to have a more indepth view on the effects of the media and the surface materials in remote sensing when using either type of energy in the sensor and specifically in the case of electromagnetic energy, certain part of the spectrum.

The tenth chapter in the book is devoted to collision avoidance. It is different from the other text and it seems a bit as if the author has shifted the focus of the book when he starts to explain methods to avoid collisions with obstacles, instead of talking about sensors. The environment mapping methods presented, like certainty grids and potential fields, are well known but the way in which the author introduces the collision avoidance methodology deserves some critic. The methodology is solely based on the idea of reactive behavioral control and no reference is given to the well-known motion planning methods. Although one can say that the reactive control has been used successfully in many laboratories or office type of interior environments, it is as clear that in many industrial or outdoor types of applications the planned obstacle avoidance is the only sensible way for the robot to move. Just think of a few tons autonomous working machine sniffing its way among the obstacles in a worksite. It is also an important problem from the sensory point to design the perception system so that enough information is available for planned collision avoidance.

The following chapters 11–15 cover the navigation sensors and systems. Again the material is well organized and presented. Gyros and their present state of art are very well described, including the physical background of optical gyroscopes. The chapter on RF-positioning systems includes besides a comprehensive description of the Navstar Global Positioning System (GPS) also an introduction to other radio beacon system developments, which are not so well-known and have been designed for local use or specific purposes. Ultrasonic and optical localization systems are surveyed with several case examples. The presentation is concluded by introducing methods to utilize special features of the environment, like walls, doorways, or ceilings, as references in navigation. This is a very important detail in mobile robotics. When using dead reckoning navigation the cumulative error must be compensated time to time by some referencing system using beacons or similar constructions. In outdoor applications, GPS provides in many cases an easy reference, but indoors it does not work and the use of special easily detectable features of the environment provides a practical and economic alternative (the same ideas are applicable outdoors, too).

The last chapter in the book deals with mission specific sensors. The author considers mainly sensors that are useful in security type of applications to detect human intruders, flooding, fire or gases in buildings, etc. Again many interesting sensors are introduced, although for quite a specific application area only.

III. WHAT IS MISSING?

What is missing? The author has succeeded in including a lot of material in the 500-page book. It is hard to say what is really missing and it is always a matter of taste. Among those subjects that I personally would have liked to see in the book is a chapter on fusing sensor information. Perhaps the easiest way, and in alignment with the general presentation in the book, could have been to introduce it via examples, e.g., how the dead reckoning navigation sensors can be fused with GPS by using a Kalman filtering approach. Another topic could be perception planning, which means planning the use of a specific sensor in a certain situation, for example to obtain the best possible perception.

The book introduces many case examples of commercial sensors or prototype developments. These examples are welcome and they illustrate well the principles discussed. As a European reader, I slightly criticize, however, the fact that most of the examples are taken from the North American market, only very few from Japan and almost none from Europe. It could have been a better policy towards overseas readers to choose the relevant examples more evenly from these markets, because in many cases such alternatives exist.

IV. CONCLUSION

It is not hard for me to say that the book by Everett is one of the best of its kind that I have ever read. This is not due to the fact that it is presently almost the only one in the field, but it is because the author has clearly set his heart on writing it and he also has a large amount of knowledge to bring along. The book has a great potential for becoming a classic. It is a good reference book because of its extensive coverage, but it is also welcome for teaching because of the consistent way it has been written.