Chapter 2
Robotic Bases

ABSTRACT

This is the second chapter of the first section. It presents the mechanical and physical foundations of mobile robots that are needed for a complete understanding of the concepts of further chapters, such as sensor and motion models. It provides a detailed review of the most common electro-mechanical components found in state-of-the-art mobile robots, emphasizing practical aspects, such as weight and size, power consumption, and performance trade-offs. Sensors and actuators, in particular, are stated as the hardware basis for coping with localization and mapping, and thus, specialized sections are devoted to them. The described devices range from low-cost sensors/actuators suitable for hobbyists to expensive professional-grade components.

CHAPTER GUIDELINE

- You will learn:
  - The most common types of robot locomotion systems.
  - A classification of sensors by the type of information they provide.
  - The physical principles behind advanced robotic sensors.
- Provided tools:
  - A glimpse at existing commercial robots and sensors.
- Relation to other chapters:
  - Motion models for each kinematic configuration are covered in chapter 5.
  - Probabilistic models for each sensor will be discussed in chapter 6.

1. INTRODUCTION

As established in the previous chapter, this book mainly focuses on mobile robots, which are indeed more interesting and have a greater potential in the service sector than static robots or robotic arms. Unfortunately, their advantages only come at the cost of an increased complexity, in both software and hardware. The first step to cope with that complexity is to provide the bases related to the mechanics and electronics of this kind of robots.

In this chapter, readers not familiarized with mobile robots will find an accessible, while thorough, overview of typical engineering designs and technologies employed in current research labs to build autonomous robots. Those already familiar with robotic sensors may also find it motivating to go through all the introduced technologies, ranging from those intended for the hobbyists to the latest developments.
A mobile robot must be able to interact with its environment through a set of basic actions. What we mean here by basic action is the execution of some set of minimal operations—in the sense that they do not invoke other actions—which are very close (and coupled) to the hardware of the robot. The set of basic actions of a mobile robot often comprises only one capability: to move around. For instance, in the case of an intelligent vehicle aimed at transporting a payload from one point to another, this capability of moving permits the design of a complete control architecture, capable of accomplishing uncountable specific tasks. More complex robots are equipped in such a way that they can also do other things, for instance grasp and manipulate objects by themselves, which exponentially increases their potential applications. In fact, moving around and manipulating objects are the two most common robot actions today, followed by the ability to communicate with humans and other machines. Just think of how many real-life tasks can be decomposed into sequences of the moving-manipulating pair of actions. Section 2 will review these and other less common robot actions, and how they are implemented in the hardware of current robots.

From the very first instant that a robot interacts with its environment, by moving itself or by manipulating other objects, there appears the need to gain some feedback from the world. For example, if a robot grasps a cup in a kitchen with the intention of taking it somewhere else, it absolutely needs to figure out whether the grasping was achieved at the intended points of the object. As another example closer to the scope of this book, when a wheeled robot intends to walk down a corridor in a straight path it needs to sense the world in order to compare the planned and the actual trajectories to avoid clashing with the walls.

Several reasons exist behind this fundamental need for feedback. First, the world may change while the robot performs its actions, which makes it necessary to constantly reevaluate the planned behavior. Secondly, the world—including the mechanical parts of the robot—will not always behave as the robot expects. In most cases the mathematical models of the robot-world interactions are only approximations (just to mention one example: wheel-ground friction while moving may lead to complex slippage behaviors), while in other cases the effects of actions must be treated as if they were random, either due to the lack of information (after trying to open a door a robot may find it was locked) or to the intractable complexity of an exact mathematical model (where all the billiard balls will end up after striking the cue ball?).

It is important at this point to stress the existence of several paradigms regarding the way feedback information is employed in automated systems. In classic control theory (Doyle, Francis, & Tannenbaum, 1992) the ultimate purpose of the system is to actuate such that a given property remains as close as possible to a desired reference level—for example, the temperature of a boiler or the speed of a motor. Solutions based on this classic control theory have been proposed to mobile robotics problems, and thus we can find in the literature examples such as visual servoing (Espiau, Chaumette, & Rives, 1993) or motion control (Quinlan & Khatib, 1993; Desai, Ostrowski, & Kumar, 1998). Unfortunately, many practical robotic tasks cannot be attacked by means of such a direct and well-studied approach. To cite one key issue central to this book: finding out its own position within the environment is a prerequisite for a mobile robot to perform a wide range of tasks—e.g. how could a robot head office 20.3 if the current robot location is unknown? As it will be explained in chapters 6 to 9, estimating the location of a robot often involves the use of intricate data fusion and statistical inference algorithms, hence localization cannot be modeled under the perspective of classic control theory.

All in all, a mobile robot absolutely needs to be equipped with sensors for gathering this essential feedback while carrying out its mission through its actuators. From section 3 on, we will
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