Part II Mobile Robots

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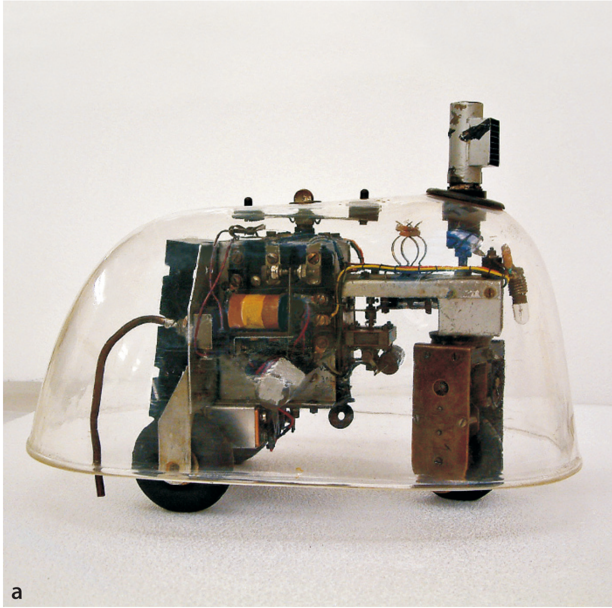
In this part we discuss mobile robots, a class of robots that are able to move through the environment. The figures show an assortment of mobile robots that can move over the ground, over the water, through the air, or through the water. This highlights the diversity of what is referred to as the *robotic platform* – the robot's physical embodiment and means of locomotion as shown in Figs. II.2 through II.4.

However these mobile robots are very similar in terms of what they do and how they do it. One of the most important functions of a mobile robot is to move to some place. That place might be specified in terms of some feature in the environment, for instance move to the light, or in terms of some geometric coordinate or map reference. In either case the robot will take some path to reach its destination and it faces challenges such as obstacles that might block its way or having an incomplete map, or no map at all.

One strategy is to have very simple sensing of the world and to react to what is sensed. For example *Elsie* the robotic tortoise, shown in Fig. II.1a, was built in the 1940s and *reacted* to her environment to seek out a light source without having any explicit plan or knowledge of the position of the light. An alternative to the reactive approach was embodied in the 1960s robot Shakey, shown in Fig. II.1b, which was capable of 3D perception and created a map of its environment and then reasoned about the map to plan a path to its destination.

These two approaches exemplify opposite ends of the spectrum for mobile robot navigation. Reactive systems can be fast and simple since sensation is connected directly to action – there is no need for resources to hold and maintain a representation of the world nor any capability to reason about that representation. In nature such



a

b

Fig. II.1.
a Elsie the tortoise. Burden Institute Bristol (1948). Now in the collection of the Smithsonian Institution but not on display (photo courtesy Reuben Hoggett collection). **b** Shakey. SRI International (1968). Now in the Computer Museum in Mountain View (photo courtesy SRI International)

strategies are used by simple organisms such as insects. Systems that make maps and reason about them require more resources but are capable of performing more complex tasks. In nature such strategies are used by more complex creatures such as mammals.

The first commercial applications of mobile robots came in the 1980s when automated guided vehicles (AGVs) were developed for transporting material around factories and these have since become a mature technology. Those early free-ranging mobile wheeled vehicles typically use fixed infrastructure for guidance, for example, a painted line on the floor, a buried cable that emits a radio-frequency signal, or wall-mounted bar codes. The last decade has seen significant achievements in mobile robotics that can operate without navigational infrastructure. Figure II.2a shows a robot vacuum cleaner which use reactive strategies to clean the floor, after the fashion of *Elsie*. Figure II.2b shows an early self-driving vehicle developed for the DARPA series of grand challenges for autonomous cars (Buehler et al. 2007, 2010). We see a multitude of sensors that provide the vehicle with awareness of its surroundings. Other examples are shown in Figs. 1.4 to 1.6. Mobile robots are not just limited to operations on the ground. Figure II.3 shows examples of unmanned aerial vehicles (UAVs), autonomous underwater vehicles (AUVs), and robotic boats which are known as autonomous surface vehicles (ASVs). Field robotic systems such as trucks in mines, container transport vehicles in shipping ports, and self-driving tractors for broad-acre agriculture are now commercially available for various applications are shown in Fig. II.4.

Fig. II.2.
Some mobile ground robots: **a** The Roomba robotic vacuum cleaner, 2008 (photo courtesy iRobot Corporation). **b** *Boss*, Tartan racing team's autonomous car that won the Darpa Urban Grand Challenge, 2007 (Carnegie-Mellon University)

Fig. II.3.
Some mobile air and water robots: **a** Yamaha RMAX helicopter with 3 m blade diameter (photo by Sanjiv Singh). **b** Fixed-wing robotic aircraft (photo of ScanEagle courtesy of Insitu). **c** DEPTHX: Deep Phreatic Thermal Explorer, a 6-thruster under-water robot. Stone Aerospace/CMU (2007) (photo by David Wettergreen, © Carnegie-Mellon University). **d** Autonomous Surface Vehicle (photo by Matthew Dunbabin)

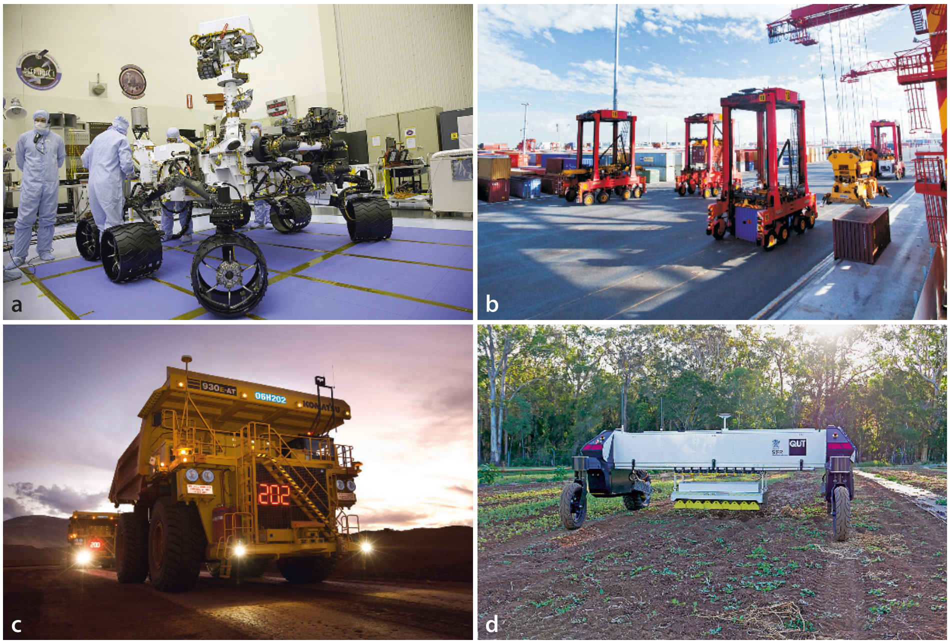


Fig. II.4. **a** Exploration: Mars Science Laboratory (MSL) rover, known as Curiosity, undergoing testing (image courtesy NASA/Frankie Martin). **b** Logistics: an automated straddle carrier that moves containers; Port of Brisbane, 2006 (photo courtesy of Port of Brisbane Pty Ltd). **c** Mining: autonomous haul truck (Copyright © 2015 Rio Tinto). **d** Agriculture: broad-acre weeding robot (image courtesy Owen Bawden)

The chapters in this part of the book cover the fundamentals of mobile robotics. Chapter 4 discusses the motion and control of two exemplar robot platforms: wheeled vehicles that operate on a planar surface, and flying robots that move in 3-dimensional space – specifically quadrotor flying robots. Chapter 5 is concerned with navigation. We will cover in some detail the reactive and plan-based approaches to guiding a robot through an environment that contains obstacles. Most navigation strategies require knowledge of the robot's position and this is the topic of Chap. 6 which examines techniques such dead reckoning and the use of maps along with observations of landmarks. We also show how a robot can make a map, and even determine its location while simultaneously mapping an unknown region.