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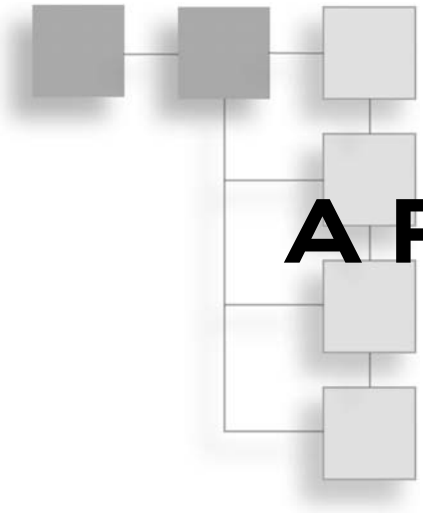
ROBOTICS

a PROJECT-based APPROACH

LAKSHMI PRAYAGA | CHANDRA PRAYAGA | ALEX WHITESIDE | RAMAKRISHNA SURI



Robotics: A Project-Based Approach

Lakshmi Prayaga, Chandra Prayaga, Alex Whiteside, and Ramakrishna Suri

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Lakshmi Prayaga, Chandra Prayaga, Alex Whiteside, and Ramakrishna Suri

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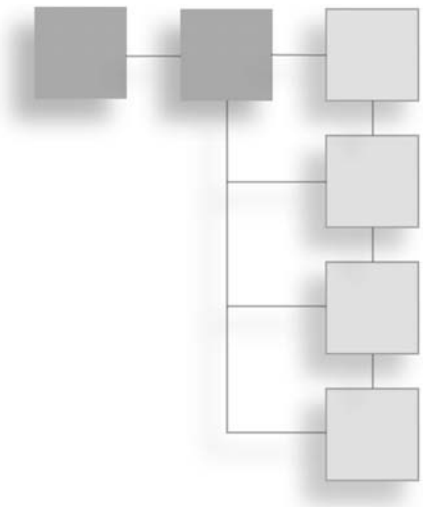

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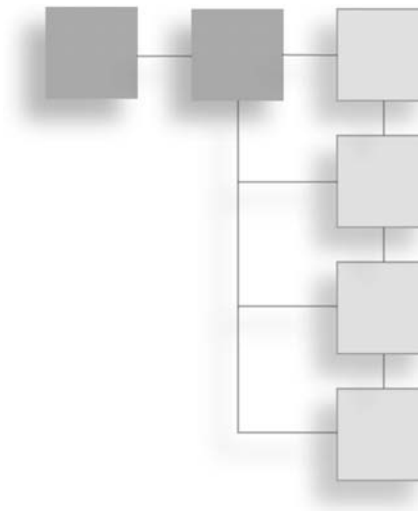
Contents



Introduction xi

Chapter 1 Introduction to Robotics 1

History of Robotics 1
What Is a Robot? 2
Robots in Commercial Applications 2
Basic Robot Navigation 3
Robots in the Military 4
Wi-Fi Networking 5
Robots in Medicine 6
Weather Monitor 7
User Interfaces 8
Security 9
Entertainment 10
Mobile Connections 10
Conclusion 10

Chapter 2 Build Your Own Robot Sweeper 11

Chapter Objectives 11
Introduction 11
Materials Required 12
Part 1: Assembling the Robot 12
Assembling the Chassis 12
Mounting the Arduino Board 13

Mounting the Ardumoto Motor Driver Shield 15
Mounting the Ultrasonic Sensor 16
Part 2: The Software 19
Using the Arduino IDE 19
Controlling the Speed and Direction of a Motor 20
Running Both Motors Using Function Calls 22
Code for the Ultrasonic Sensor 24
Part 3: Putting It All Together 26
Complete Code for the Sweeper Robot 27
Conclusion 32

Chapter 3 Traveling Robot 33
Chapter Objectives 33
Introduction 33
Materials Required 34
Part 1: Line Sensor 34
How Does a Line Sensor Work? 34
Assembling the Robot with the Sensors 36
lineSensorChk Sketch 37
Using the lineSensorChk Sketch 38
How the lineSensorChk Code Works 39
Part 2: Line Tracking 39
LineTracker Sketch 40
How the Code Works 42
Part 3: Learning to Use the Color Sensor 43
Connections between the Color Sensor Pins and Arduino Board Pins 47
lineClrSensor Sketch for Testing the Line Sensors and the Color Sensor 48
Testing the lineClrSensor Sketch 49
How the Code Works 51
Part 4: Making the Robot Follow a Track and Stop at a Specific Point for a Prescribed Time 51
lineandColorSensorTest Sketch 51
How the Code Works 55
Conclusion 56

Chapter 4 Intruder Alarm 57
Chapter Objectives 57
Introduction 57
Materials Required 58

Activity 1: Intruder Alarm with a Diode Laser and Photoresistor 58
Sketch to Control the Laser 61
How the Code Works 61
Sketch to Control the Photoresistor 61
How the Code Works 63
Sketch Combining the Laser and the Photoresistor 64
How the Code Works 64
Activity 2: Proximity Alarm with an Ultrasonic Range Sensor 65
Sketch for the Proximity Alarm 66
How the Code Works 67
Activity 3: Touch Sensor and Alarm 67
Sketch for the Touch Sensor 68
How the Code Works 69
Activity 4: Keyboard and LEDs 69
Sketch to Light Up LEDs with Touch 70
How the Code Works 72
Conclusion 72

Chapter 5 Robot Networking and Communications with Wi-Fi 73

Chapter Objectives 73
Introduction 73
Materials Required 75
Part 1: Installing the Wi-Fi Sensor and Connecting to Your Network 75
Connecting to an Open Network 79
Connecting to a Closed Network 80
Part 2: Creating a Telnet Server 81
For Microsoft Windows Users 83
For Mac/Linux Users 84
The Complete Sketch 85
Conclusion 88

Chapter 6 Robot Medical Assistant 89

Chapter Objectives 89
Introduction 89
Materials Required 90
Program Components and Connections 90
Pill Reminder Sketch 94
How the Code Works 96
Conclusion 99

Chapter 7 Data Logger 101
Chapter Objectives 101
Introduction 101
Materials Required 102
Part 1: Measuring and Displaying Ambient Temperature 102
Hardware Connections 103
Writing the Sketch 106
How the Code Works 107
Part 2: Data Logging Activities 108
Activity 1: Initializing the SD Card Reader 109
Activity 2: Writing Data to an SD Card 111
Activity 3: Reading Data from a File 115
Activity 4: Logging Temperature Data 117
Conclusion 120

Chapter 8 Remote-Controlled User Interfaces 121
Chapter Objectives 121
Introduction 121
Development Software 122
A Graphical Control for Arduino 124
Materials Required 125
Introduction to Java 125
Downloading and Installing NetBeans 126
Networking in Java 127
Creating the User Interface 131
Optional Activities 138
Conclusion 139

Chapter 9 Security Robot 141
Chapter Objectives 141
Introduction 141
Materials Required 142
Setting Up the Hardware 142
The Complete Relevant Code Blocks 146
Variable Setup 146
Capture Photo Function 146
Conclusion 148

Chapter 10 Light and Sound 149
Chapter Objectives 149
Introduction 149
Materials Required 149
Part 1: Connect the NeoPixel Ring to the Arduino and Program Pixel Colors 150
pixelColor0 Sketch 154
How the Code Works 156
pixelColor1 Sketch 157
How the Code Works 158
pixelColor2 Sketch 159
How the Code Works 161
Part 2: Attaching the Microphone 162
soundSensor1 164
How the Code Works 164
Part 3: Putting It All Together 165
soundLight4 166
How the Code Works 167
Conclusion 168

Chapter 11 Android App Controller 169
Chapter Objectives 169
Introduction 170
Materials Required 170
Part 1: Getting Ready for Android 170
Android Programming Architecture and Language 171
Installing the Android Developer Kit 172
Installing the Genymotion Android Emulator 175
Creating a Sample Application 180
Part 2: Creating an Arduino Controller App 185
Conclusion 198

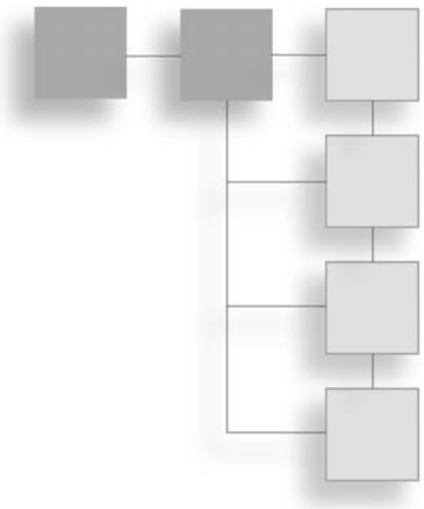
Chapter 12 Additional Robotics Applications 199
Robots in Medicine 199
Robots in Education 200
Robots in the Military and Law Enforcement 201
Robots in Industrial Applications 202
Trends in Robot Types 202
Soft Robotics 202
Swarm Robots 203
Conclusion 204

Appendix A Materials Required for the Projects. 205

Glossary 209

Index 213

Introduction



This book is designed to provide an introduction to applications of robotics. It is designed for absolute beginners, such as teens and those who wish to venture into the field of robotics. Several fun-filled activities are presented in the book, including a robot sweeper, a medical assistant, and a security robot.

How This Book Is Organized

This book is organized as a project-based approach to learning robotics. Each chapter includes a project that you can build and complete. Materials required for each project are listed in the beginning of each chapter, and a complete list of all materials for all the projects is provided in Appendix A.

Companion Website Downloads

The source code for all projects is available on the companion website at:
www.cengageptr.com/downloads

A set of videos demonstrating how to build each project is also available for purchase.

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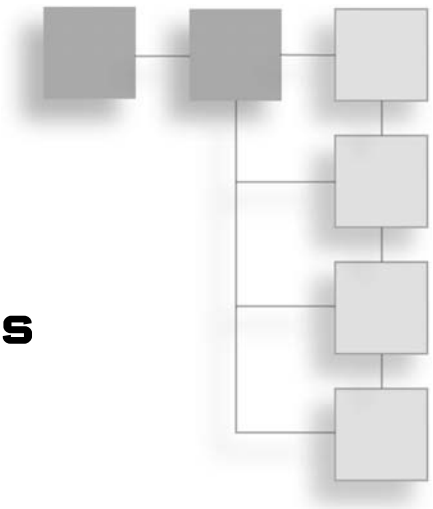
Chapter 1



Introduction to Robotics

Robotics is an exciting interdisciplinary topic—the foundations of which rest on principles from various disciplines, including computer science, physics, engineering, and mathematics. Applications of robotics are varied and their scope is limited only by human imagination. This chapter presents a discussion of the definition of a robot, a variety of robotics applications, and a quick synopsis of the robotics projects that you will build in each chapter in this book.

History of Robotics

The notion of robotics can be traced back to as early as 320 B.C. when the Greek philosopher Aristotle writes in his famous book *Politics:*

> *"If every tool, when ordered, or even of its own accord, could do the work that befits it... then there would be no need either of apprentices for the master workers or of slaves for the lords."*

Since then researchers have been working in the field of robotics for a long time. In fact, the following link provides a neat timeline on the evolution of robotics from researchers at the University of Auckland: http://robotics.ece.auckland.ac.nz/index.php?option=com_content&task=view&id=31

As you can see, the idea of a robot was in use in the 1400s, and the notion of an *artificial being* was introduced in the 1700s. In the 1900s, the word "robot" was first used in the context of a play, and the word robot was described as something that lacks emotions. In the 1940s, British scientists designed the first autonomous machine, and in 1950 came the

famous Turing test, in which Alan Turing proposed a test to determine whether machines could think. The 1970s and 1980s produced several advances in the design of robots with the introduction of mechanically controlled arms and other mobile robots that could be used in industry. The 1990s produced human-like robots that could be used in games such as soccer. The new millennium (2000 until the present time) brought in advanced robotics in commercial and household applications. We see robots used as vacuum cleaners, mail delivery agents, surgeons in hospitals, and in many more situations. We also see new designs of robots such as flying drones that could be more suitable for some applications. In fact, robotics is becoming so pervasive in our daily lives that researchers in Auckland, New Zealand, predict that by 2020 the demand for robotics will become so high that there will be a dearth of engineers and programmers to meet this new demand.

What Is a Robot?

A quick search on the Internet provides several attempts at defining what a robot is. For our purposes, we define a robot as *a mechanical device that can perform a given task depending on the instructions it is given.* So, how is this different from a computer or a machine? Unlike a computer or a machine that performs a given task, typically, a robot not only performs the task given to it, but it is also able to use artificial intelligence (AI) and *learn* from its experiences while performing given tasks. However, in this book we will limit our discussion to the application of robotics in various disciplines and the understanding of how to design robots that can perform tasks related to specific disciplines or fields such as health care, military, law enforcement, etc.

Robots also come in various shapes and styles designed to accomplish specific tasks. Some robots are shaped like mechanical arms that perform tasks requiring arm-like limbs, such as lifting objects, placing items, drawing on a board, and other such tasks. Some robots are shaped like vehicles, such as unmanned cars, flying drones, underwater ships, and so on. So we see that robots have various shapes and styles for different purposes.

The chapters in this book are aligned to various applications and domains of robotics and include a project that demonstrates how robots are being used in those domains. In this first chapter, you will find a discussion of some applications of robotics in various aspects of real life.

Robots in Commercial Applications

Robots are making their way into our daily lives. There are several commercial robots suitable for a variety of needs. Chapter 2, "Build Your Own Robot Sweeper," describes how to build a simple version of a commercial application of robotics. A robot vacuum cleaner

(such as the Roomba) is an example of a commercial application of robotics, sold as a consumer electronic device. While designing such an efficient robotic vacuum cleaner is a complex process involving sophisticated artificial intelligence algorithms and electronics, it is possible to mimic its basic behavior and design a robotic sweeper using simple components. This chapter guides you in building a simple robotic sweeper, as seen in Figure 1.1.

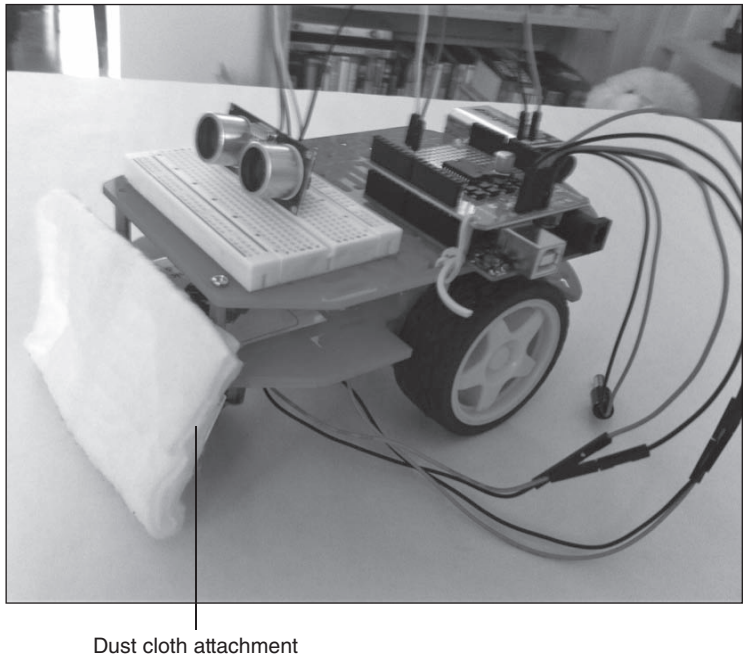


Figure 1.1
Robot sweeper.

Basic Robot Navigation

Navigation is one of the basic features for a robot. Chapter 3, "Traveling Robot," introduces basic navigation mechanisms that help the robot navigate using line tracking (Figure 1.2). You will also learn how the robot can detect colors along its path. This feature can become a good option for making the robot take different paths depending on the color detected. You will learn how to use a line-tracking algorithm and a color sensor.

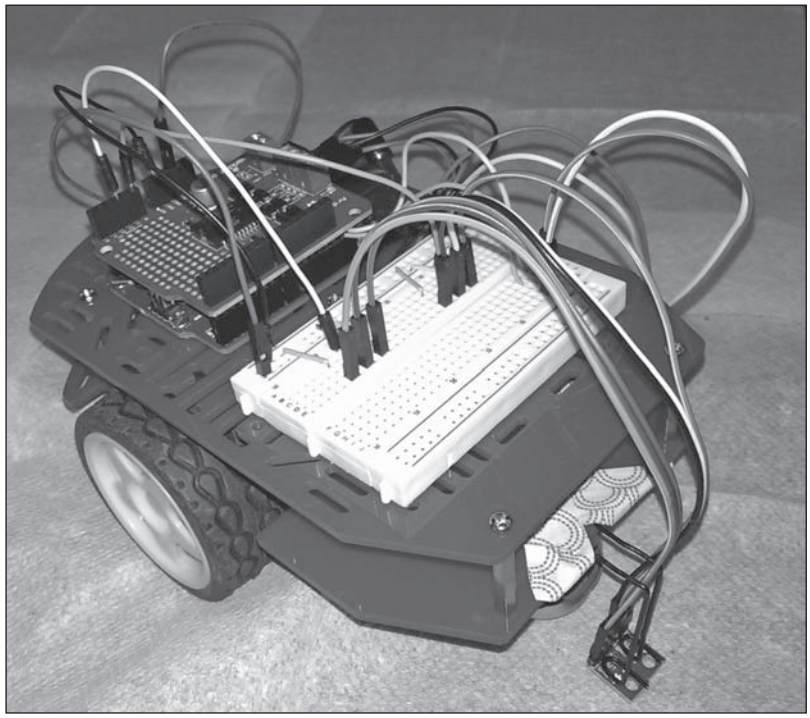


Figure 1.2
Navigating robot with sensors.

Robots in the Military

The role of robotics in the military is extremely important, and robots are being used in ingenious ways in this area. An example of this is the use of drones. In all these applications, one aspect of robotics is of paramount importance: the notion of intrusion detection. This capability triggers the robot to take the necessary defensive actions and thwart danger. Chapter 4, "Intruder Alarm," guides you through building a robot equipped with proximity sensors that can detect intrusion and trigger the robot to raise an alarm. Typical combat robots are equipped with several sensors, including optical, proximity, and infrared sensors, which are able to detect intrusions and raise alarms. Figure 1.3 shows the Arduino microcontroller with the alarm detection sensor attached to it.

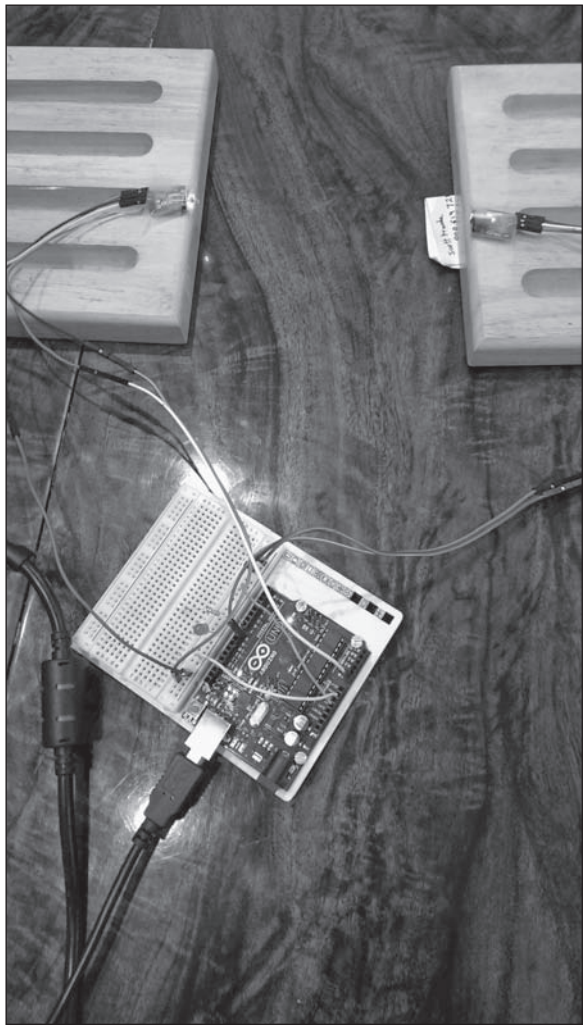


Figure 1.3
Alarm detection sensors.

Wi-Fi Networking

A principle feature of robots is their mobility, which requires autonomy and un-tethered connections for power, communications, and sensors. While various technologies can provide the wireless features required for modern robots, none match the simplicity and effectiveness of Wi-Fi for basic uses (Figure 1.4). In Chapter 5, "Robot Networking and Communications with Wi-Fi," you will learn about the client–server paradigm, with an emphasis on networked robots. You will set up a basic server on your robot and

communicate with it over your home Wi-Fi network to issue commands from your computer, no wires required. This project in Chapter 5 extends all other projects so far, allowing those projects to take place remotely, with data sent to the user's computer without a serial connection.

Figure 1.4
Robot with Wi-Fi shield.

Robots in Medicine

Robots are being used extensively in various capacities in the medical field. Robots are being used both at a very simplistic level as simple data-capturing kiosks in tele-medicine, as well as performing highly skillful surgeries in a physical hospital. In Chapter 6, "Robot Medical Assistant," the assistant project presents you with step-by-step instructions for designing a robot that can be used to remind a patient to take pills at a particular time—essentially, a pill reminder (Figure 1.5). The logic can then be extended to program the robot to monitor the patient's temperature or sugar levels, etc., and truly transform the robot into a personal medical assistant.

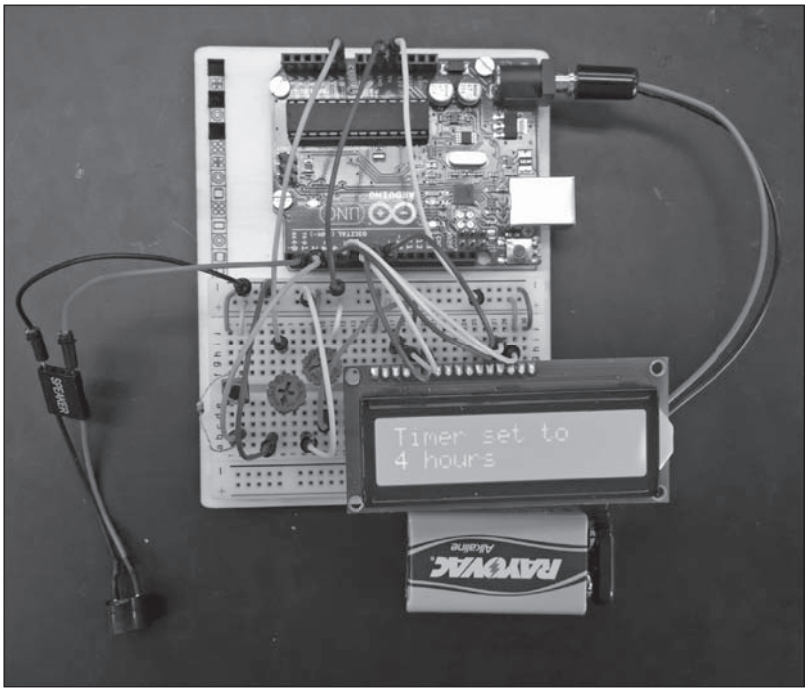


Figure 1.5
Robot with timer capabilities.

Weather Monitor

Weather monitoring is a very complex and highly computationally intensive task. Computers can be very efficient in calculating, analyzing, and making forecasts from given data sets. In weather related problems, meteorologists work with large data sets, model them, and predict weather patterns as we see in cases of hurricanes, tornados, and other weather related issues. Chapter 7, "Data Logger," walks you through building a simple temperature monitoring application where you can monitor the temperature and log it to an SD card (Figure 1.6).

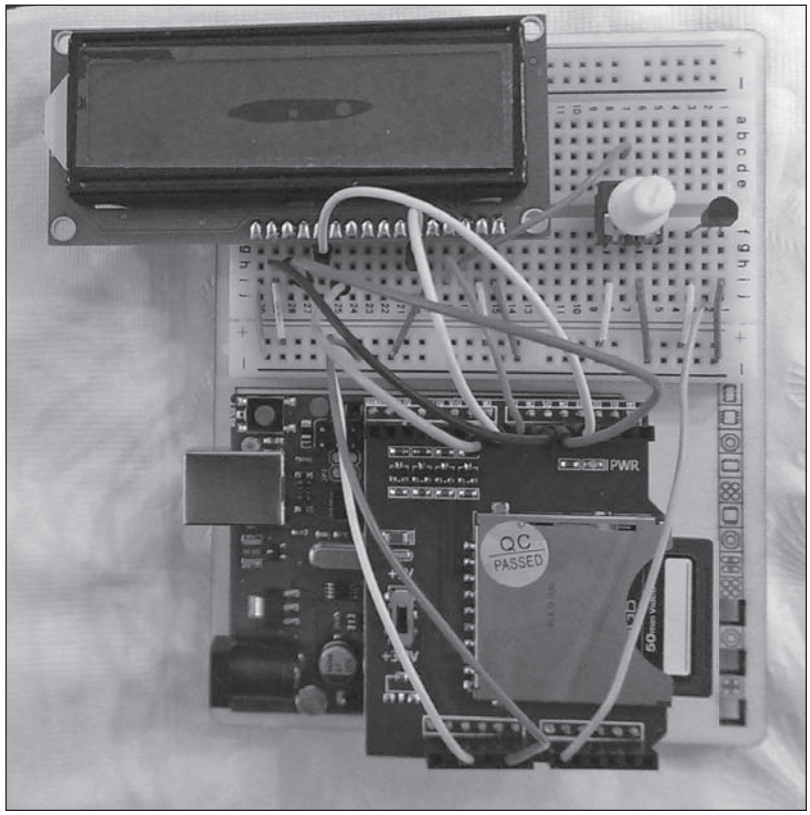


Figure 1.6
Robot with temperature sensor and data logger.

User Interfaces

In the modern technical age, text based data has evolved into a much prettier picture. Nearly every consumer application provides a graphical user interface (GUI) to make the solution as easy and fun to use as possible. Chapter 8, "Remote-Controlled User Interfaces," analyzes the leading graphical user interface packages and their use in industry. You will then create a JavaFX application that will connect to your robot over Wi-Fi. You will learn to design beautiful interfaces using FXML- and CSS-based technologies, and then implement the functionality in high-level Java code (Figure 1.7). This code will link to your Wi-Fi server developed for your robot and execute commands and return data at the push of a digital button.

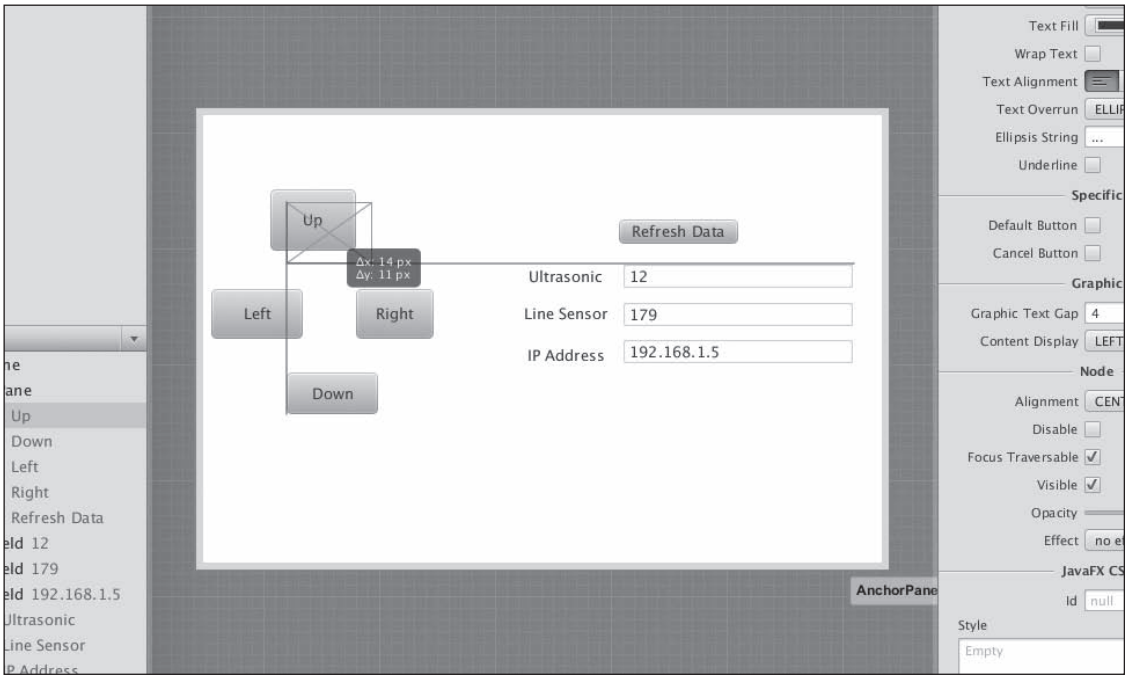


Figure 1.7
UI for the robot.
Source: Oracle.

Security

One of the most remarkable increases in the technology revolution is that of camera sensors. Shrunken down to centimeter-wide lenses with incredible data speeds, just about every device comes equipped with a camera, resulting in a remarkable number of images on a global scale. In Chapter 9, "Security Robot," the project introduces you to a basic camera technology through the development of a security robot (Figure 1.8). This robot is capable of driving to a remote location via the previously created interface and then snapping a picture and sending it over the Wi-Fi network to the GUI, where it will be displayed.