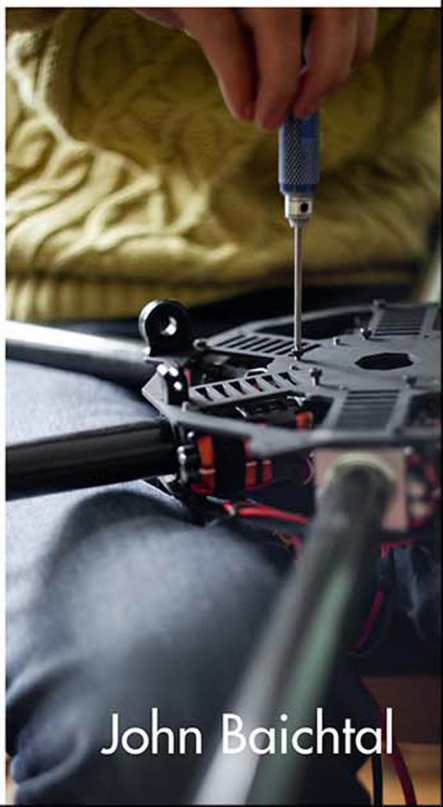
BUILDING YOUR OWN DRONES

A Beginner's Guide to Drones, UAVs, and ROVs



John Baichtal

que

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John Baichtal

que®

800 East 96th Street,
Indianapolis, Indiana 46240 USA

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About the Author

John Baichtal has written or edited over a dozen books, including the award-winning *Cult of LEGO* (No Starch Press, 2011), *LEGO hacker bible Make: LEGO and Arduino Projects* (Maker Media, 2012) with Adam Wolf and Matthew Beckler, *Robot Builder* (Que, 2014), and *Basic Robot Building with LEGO Mindstorms NXT 2.0* (Que, 2012). His most recent book is *Maker Pro* (Maker Media, 2014), a collection of essays and interviews describing life as a professional maker. John lives in Minneapolis with his wife and three children.

Dedication

This book is dedicated to my Grandma Marion, who is a couple months shy of her 98th birthday as I write this. She was in the hospital a few weeks ago with heart problems and the doctors told her to get her affairs in order, and sent her home in hospice. Grandma isn't ready to leave the party, however, and she's been feeling better, buoyed by the great care she's received from my mom and aunt. Her love of life and passion for writing give me strength every day.

Acknowledgments

When thinking of my family, I am confronted by two irrefutable facts:

1) Arden, Rosemary, and Jack are the best kids anyone could ask for.

2) None of this would mean anything without my dear Elise. I love you!

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My mom, Barbara, compiled the Glossary, and I am forever indebted to her for helping out, in this and so many other things.

We Want to Hear from You!

As the reader of this book, you are our most important critic and commentator. We value your opinion and want to know what we're doing right, what we could do better, what areas you'd like to see us publish in, and any other words of wisdom you're willing to pass our way.

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Introduction

Drones are in the news all the time—and let's face it, they're likely to be an increasing part of our lives. We can throw on a tinfoil hat and look for small helicopter-shaped shadows, or we can learn as much as we can about these interesting devices. I suggest the latter—there is a lot of cool technology out there, and the best way to control it is to understand it.

Who This Book Is For

Aspiring drone-builders of all stripes will appreciate this book, as it covers many different areas of building your own drone projects, including not only electronics, but motors, airframe-building techniques, and tools.

How This Book Is Organized

This book consists of a main project, a quadcopter you'll build over the various chapters. The alternating chapters describe a variety of projects such as a data-gathering rocket drone, a blimp, and a boat made out of soda bottles, giving you a perspective on drones beyond those quadcopters that have everyone abuzz.

- Chapter 1, "A History of Drones," consists of a history of drones and brings you up to speed on current technological limits and terminology drone pilots use.
- Chapter 2, "Showcase of Cool DIY Drones," describes a dozen cool drones, including UAVs (unmanned aerial vehicles), ROVs (remotely-operated underwater vehicles), and rovers built by hobbyists and amateurs alike.
- Chapter 3, "Overview of Commercial Drones and Kits," introduces a number of commercial drones that you might care to purchase. Everything from a quadcopter packing a video camera to an undersea explorer is on the table.
- Chapter 4, "Building a Quadcopter I: Choosing an Airframe," begins the quadcopter project as you learn about a variety of airframes and chassis products, and you begin building your quadcopter's airframe out of a kit.
- Chapter 5, "Rocket Drone Project," breaks from the quadcopter and has you build a rocket drone, a model rocket with a basic Arduino payload.

- Chapter 6, "Building a Quadcopter II: Motors and Props," discusses two key components of your quadcopter build. You are presented the various options for purchasing motors and propellers, and you are shown how to mount them onto your quadcopter's airframe.
- Chapter 7, "Blimp Drone Project," shows you how to build a blimp drone, a small wooden robot hoisted aloft by helium balloons.
- Chapter 8, "Building a Quadcopter III: Flight Control," shows you how to control your robot while its in the air, with flight controllers and electronic speed controllers doing most of the work.
- Chapter 9, "Drone Builder's Workbench," covers the various tools I used to build the projects in the book.
- Chapter 10, "Building a Quadcopter IV: Power Systems," introduces a very important topic: how to power your quadcopter. This includes instructions on building a power distribution system to deliver electricity to the motors.
- Chapter 11, "Waterborne Drone Project," demonstrates how to make a simple remotely-operated vehicle build out of soda bottles.
- Chapter 12, "Building a Quadcopter V: Accessories," covers the variety of accessories, such as camera mounts, available for purchase or creation.
- Chapter 13, "Making a Rover," shows you how to make a rolling robot that uses RFID tags to navigate.
- Chapter 14, "Building a Quadcopter VI: Software," profiles some flight control software and autopilot firmware and also explores the ins and outs of the control software of the autopilot we used in the copter project. With the conclusion of the book, you will complete the quadcopter build.
- Finally, the Glossary explains the various terms used throughout the chapters.

If you have any questions, or want to learn more about the projects and my other books, the best way is to check out my Facebook page, www.facebook.com/baichtal. You can also email me at nerdyjb@gmail.com or follow my Twitter feed @johnbaichtal. Good luck and happy drone building!

1

A History of Drones

Imagine a car without a driver or a plane without a pilot, with a computer replacing the person who operates the vehicle. You're imagining a drone.

Drones are everywhere in the news, especially with battlefield stories about unmanned aerial vehicles (UAVs) shooting missiles at targets half a world away from the person pressing the button. However, not all drones are used in war. Some drones are peaceful drones.

Budget cuts at NASA have thrust these remotely operated probes into the spotlight—first and foremost the Mars rovers (see Figure 1.1). These remotely controlled rollers have performed vastly beyond the expectations of NASA's engineers.

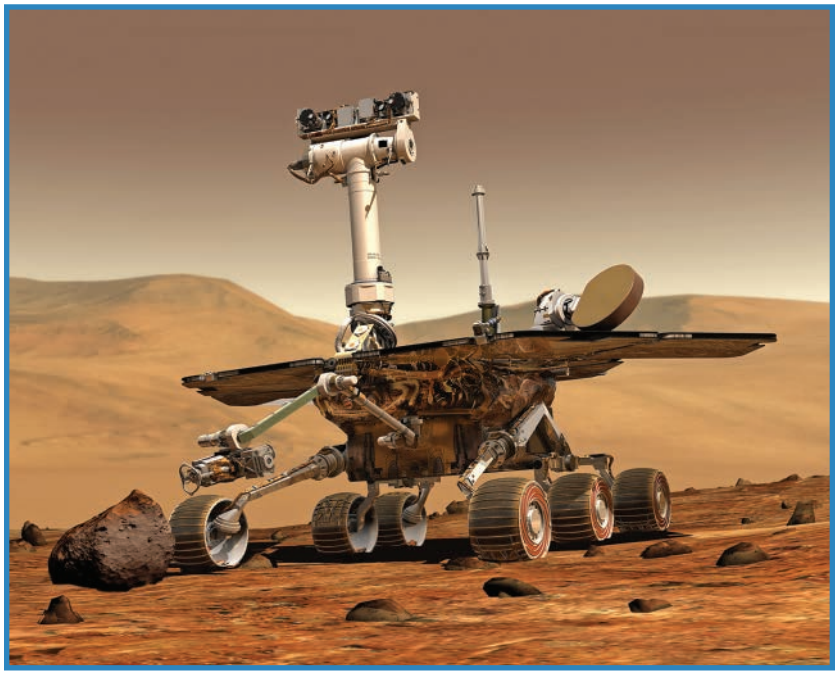

FIGURE 1.1 An artist's concept drawing of a Mars Rover (credit: NASA/JPL/Cornell University).

Governmental use of drones is one thing, but do amateurs also use drones? The answer is yes. Ordinary hobbyists, tinkerers, and small business owners make and operate their own drones. For example, winemakers fly camera-equipped quadcopters (miniature four-bladed helicopters) to observe the state of their foliage in the arbors, without leaving their house. Other entrepreneurs flying similar quadcopters have upended the aerial photography business by eliminating the need for full-sized helicopters. Amazon and other companies are exploring package delivery by drone.

The purpose of this book is to introduce you to the current state of quadcopters, UAVs, ROVs (remotely operated vehicles), and other variants of the technology, with an opportunity to work on simple drone projects such as a rocket with an accelerometer aboard it, a water-borne drone, and a blimp bot made from Mylar balloons. Simultaneously, you'll follow along as I detail the careful assembly of a quadcopter, thus enabling you to build your own or learn how to make one even better.

What Is a Drone?

Let's get one thing clear: The definition of "drone" isn't really all that clear.

Drones get their name from honeybee drones, which go about their tasks mindlessly, as they are controlled by a faraway queen. Similarly, a robotic plane with a microcontroller programmed to work as an autopilot works much the same way, albeit with the help of technology.

Devices described as drones fall into two basic camps. First, there are *autonomous robots* whose operators take active control as needed. The rest of the time, autopilots take the lead, theoretically allowing a single operator to manage multiple craft. However, when the need arises, the operator can disable the autopilot and take back control.

The second camp involves quadcopters and other "helicopter-esque" flyers. The public sometimes calls these drones, despite the fact that most of them are merely radio-controlled (RC) models and not autonomous. Perhaps the reason why the two definitions have merged is that multirotors have recently become a great platform for autopilot-driven, microcontroller-based autonomous flight.

Hobbyists are operating swarms of quadcopters, creating new games where the drones compete against each other, and they are packing everything from cameras to barometric sensors and ultrasonic rangefinders into their creations. Meanwhile, a huge education market has developed, with teenagers and younger children building autonomous robots using building sets such as LEGO Mindstorms and VEX.

We're in the infancy of a cool phenomenon, and we can be a part of it! Let's build some drones together.

Three Terrains

Drones are differentiated by the terrain the vehicle traverses:

- Unmanned aerial vehicles (UAVs)
- Remotely operated vehicles (ROVs)
- Rovers

These three types of drones are discussed in the following sections.

Unmanned Aerial Vehicles

The term *unmanned aerial vehicle* describes drone airplanes (such as the Predator shown in Figure 1.2) and helicopters. Pretty much, if it operates in the air, we'll call it an UAV. The most popular hobbyist UAV is the quadrotor or quadcopter, and because of its popularity, this book will focus on this type of UAV.

FIGURE 1.2 The Predator drone did much to teach the public about drones and how they work (credit: U.S. Air Force).

UAVs most often are controlled through radio waves, such as the signals generated by an RC handset. Others use Wi-Fi or cellular technology to communicate. Many also include GPS receivers so their flights can be tracked on a map.

Remotely Operated Vehicles

A remotely operated vehicle is an underwater drone, usually tethered to a boat or submersible by a data wire, which is necessary because radio waves are dramatically hindered by water. ROVs have been used by ocean explorers for years. You can see an example of an ROV in Figure 1.3.

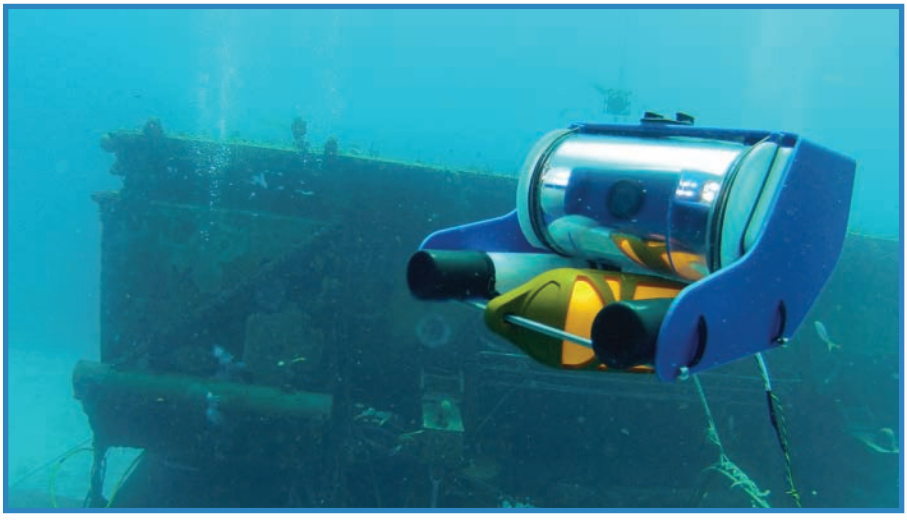

FIGURE 1.3 The OpenROV explores a shipwreck (credit: OpenROV).

Rovers

A *rover* is an RC car with extra features. It rolls around and navigates an earthbound terrain using sensors to detect obstructions. Rovers often feature tank treads or knobby tires, like the one shown in Figure 1.4. This helps them traverse uneven ground. Being ground-based gives rovers the capability to use all sorts of sensors to navigate, including ultrasonic, RFID, and bump sensors. You'll build a rover in Chapter 13, "Making a Rover."

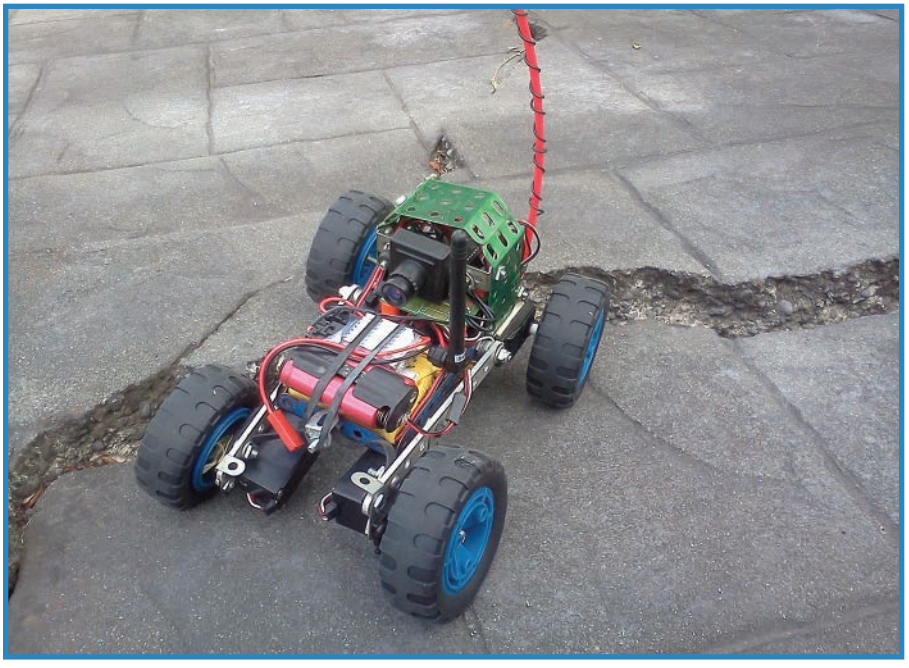

FIGURE 1.4 This camera-mounted rover sports knobby tires for rough terrain (credit: Geoffrey Irons).

Anatomy of a Drone

Every homemade drone will differ from the next; that said, most drones have a number of features in common. The following are commonplace quadcopter components. Follow along with Figure 1.5 to see how each part fits into the full project.

A. **Props**—The props of a quadcopter typically consist of two standard and two "pusher" props rotating in opposite directions.

B. **Motors**—Quadcopters use DC or AC motors. There are countless varieties and price points, with premium motors catering to wealthy tinkerers. In Chapter 6, "Building a Quadcopter II: Motors and Props," I go into detail on a number of great hobbyist-friendly motors.

C. **Electronic speed controllers (ESCs)**—ESCs convert DC to AC for brushless motors, and also trigger the motors' power supply. You'll need one for each motor. ESCs' firmware can be modified to create different motor behaviors. For instance, ESCs are often configured to slow down the motor rather than stopping abruptly.

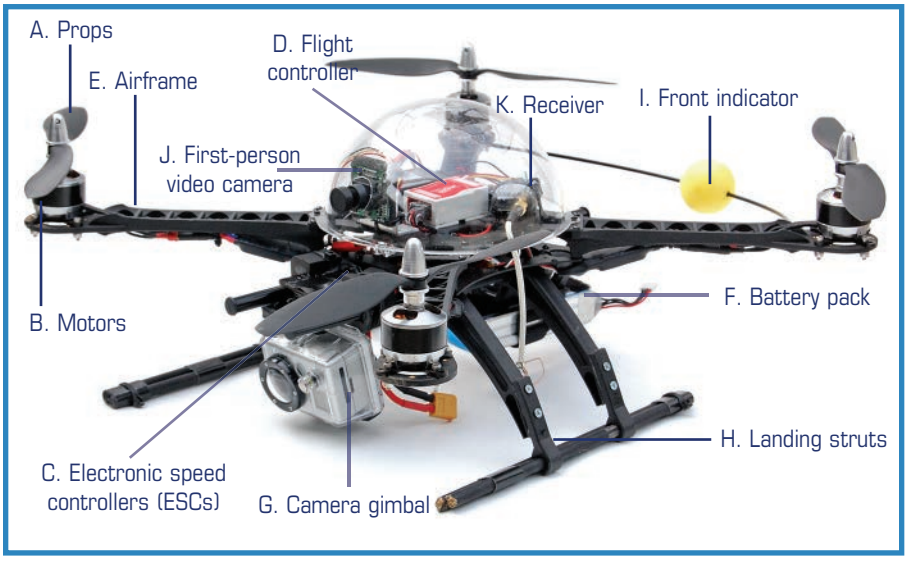

FIGURE 1.5 The quadcopter has a lot of parts and equipment (credit: Steve Lodefink).

D. Flight controller—The flight controller assists manual flight with certain autonomous functions. For instance, many flight controllers have a tilt sensor that keeps the drone level. Oftentimes flight controllers will have a certain pre-programmed routine they perform if the quadcopter leaves the control range.

E. Airframe—*Airframe* is the proper name for the drone's chassis. The airframe consists of a number of different elements, including motor booms as well as an enclosure or platform for housing the electronics.

F. Battery pack—Often a LiPoly battery, the robot's battery pack keeps the propellers turning while also powering whatever electronics are onboard.

G. Camera gimbal—This is a rotating platform on which a video camera is mounted. Servomotors allow the operator to turn and angle the camera during flight.

H. Landing struts—Quadcopters with a camera gimbal or other protuberance on the bottom need landing struts, which are little legs the drone rests on when it's on the ground. On the other hand, drones without gimbals often don't need struts, and simply land with the entire airframe on the ground.

I. Front indicator—Quadcopter operators need to know the front of the hovering aircraft, and it might not necessarily be obvious. Multiple solutions are available, ranging from differently colored props, LEDs, and reflective material—or in the case of the quadcopter in Figure 1.5, a colored ball that marks the *rear* of the craft. All that matters is that it makes sense for you!

J. **First-person video camera**—Low-resolution camera that sends its images to a ground station via radio waves.

K. **Receiver**—This small box translates radio signals into instructions for the flight controller.

Summary

In this chapter, you learned about drones, their common configurations, and the various components that go into them. In Chapter 2, "Showcase of Cool DIY Drones," you'll see what other folks have done with the technology. You'll be surprised at the diversity of all of the cool projects out there!

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2

Showcase of Cool DIY Drones

So you want to build your own drones? Awesome. The best way to start is to admire the work other people have done. The following 12 projects are just a sampling of all the cool DIY (do-it-yourself) work you can find out in the wild!

Bicycle Rim Quadcopter

This project bears out the truism that pretty much anything can be made into a quadcopter's chassis, so long as it's reasonably light and strong. Built by Sam Ley, this quadcopter (pictured in Figure 2.1) flies very well and has survived several crashes.

You'll buy or build your own airframe in Chapter 4, "Building a Quadcopter I: Choosing an Airframe," but as you make your decision, look back on this crazy quadcopter and know that you have a lot of options.

3D-Printed Mini Quadcopter

This airframe, designed by Thingiverse user Brendan22, comes in a variety of configurations, including the four-bladed mini-drone shown in Figure 2.2. Another, the T-6, consists of three booms with two motors and propellers each. You can find Brendan22's designs at the following website: http://www.thingiverse.com/Brendan22/.

This is another example of a DIY airframe that you should consider when you make your own in Chapter 4. You can save yourself tons of time by taking advantage of free resources like Thingiverse to simply manufacture the parts you want. Simple if you have a 3D printer, of course!

FIGURE 2.1 Sam Ley made clever use of found material to make his quadcopter's airframe (credit: Sam Ley [CC-A]).

FIGURE 2.2 Have an idea for an airframe design? Just print it out! (credit: Brendan22)

Clothesline Racer

This autonomous robot, built by Mike Hord, follows a clothesline or cable to its terminus, then reverses course. It's a very simple drone, but a drone nonetheless! It has a very rudimentary control system—an ultrasonic sensor that tells the microcontroller to reverse the motor—and no steering. You can see the racer in Figure 2.3.

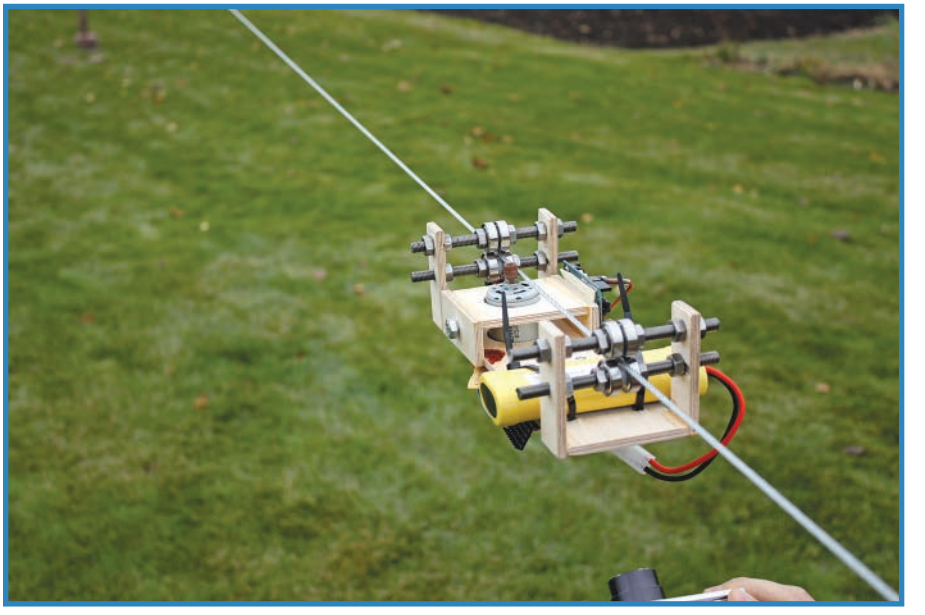

FIGURE 2.3 This autonomous line-following robot goes back and forth (credit: Pat Arneson).

The racer goes to show that drones can look like anything. Don't be roped into just one category when building a drone. Four chapters of this book detail non-quadcopter drones, including a rocket, a blimp, a boat, and a car.

Vessels

Vessels is a project by Stephen Kelly, Sofian Audry, and Samuel St. Aubin, consisting of dozens of small floating robots (shown in Figure 2.4) that scoot around a pool, communicating with each other with infrared signals and audio tones. The idea is that they're almost behaving like emergent living beings. You can learn more about the Vessels project at http://vessels.perte-de-signal.org/project/.

Chapter 11, "Waterborne Drone Project," details a floating drone that uses a computer fan to move around. Simple, slow-moving boats like these are great for backyard experimentation, because you can test it out very easily!

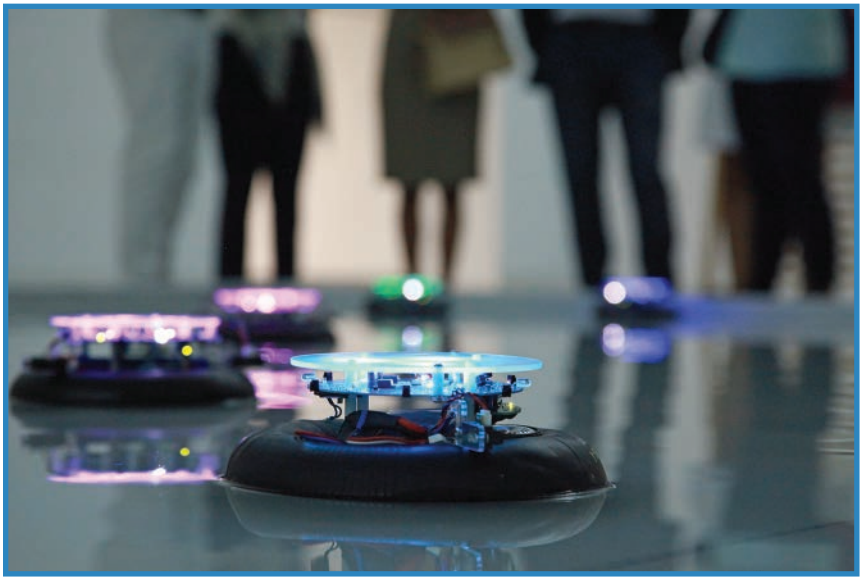

FIGURE 2.4 These autonomous robots actually act somewhat like living beings (credit: Beatriz Orviz, LABoral [Spain]).

Radio-Controlled Blimp

This blimp, built by robotics students and instructors at Idaho State University, uses two DC motors for the propellers, each angled by a servomotor so it can turn independently (see Figure 2.5). The operator controls the blimp using a custom handheld control unit; XBee wireless cards in the blimp gondola and controller communicate with each other. You can learn more about this project at http://www.thingiverse.com/thing:98815.

In Chapter 7, "Blimp Drone Project," you'll have your own chance to build a blimp, using a laser-cut wooden gondola supporting a pair of motors, with a radio-control receiver on-board.

FPV Quadcopter

Steve Lodefink's beautiful copter never looked this good again—mostly because the next flight after this photo was taken, it suffered a failure, fell out of the sky, and smashed to pieces on the ground (see Figure 2.6). It had two cameras: a low-resolution FPV (first-person video) camera that transmitted a picture over the radio waves, and a GoPro Hero2 camera for high-resolution shots.

A beautiful drone like this one demonstrates why it is such a popular category. You'll build a quadcopter (smaller and simpler than Steve's) in stages throughout this book.