Build and Program Your Own LEGO® MINDSTORMS® EV3 Robots

Marziah Karch

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Marziah Karch

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800 East 96th Street,
Indianapolis, Indiana 46240 USA

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About the Author

Marziah Karch enjoys the challenge of explaining new gadgets and complex technology to beginning audiences. She is the author of several books, including *Android Tablets Made Simple*. Her writing has appeared in *Wired* magazine, About.com, and the GeekMom blog on Wired.com.

Marziah is a senior instructional designer for NWEA in Portland, Oregon. She holds a master's degree in Instructional Design and is working on a Ph.D. in Library and Information Management. When she's not feeding her geek side with new gadgets or writing about technology, Marziah enjoys life in the Pacific Northwest with her husband and two children, all of whom are LEGO enthusiasts.

Dedication

This book is dedicated to Pari and Kiyan. Keep on building.

Acknowledgments

I'd like to thank Melissa Kelly for her photos, robot club attendance, and enthusiasm. Ada and Jay also get credit for helping. I hope they build amazing robots. Harold spent countless hours helping me build every single one of those demo robots. Travis Coon over at LEGO Education/Pitsco was amazingly helpful with demos and previews and suggested resources. Finally, I'd like to thank the wonderful editorial staff at Pearson for everything they did to bring this book to press.

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.

We welcome your comments. You can email or write to let us know what you did or didn't like about this book—as well as what we can do to make our books better.

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Introduction

If you've been looking for a fun introduction to robotics without having to solder wires or learn advanced programming languages, the LEGO MINDSTORMS EV3 is just the ticket. You can make and program robots using a graphical interface and LEGO interlocking parts. When you're ready for a new challenge, you can hack the operating system and use more advanced languages such as Java. You can also connect EV3 robots to harness the combined computing power or have EV3 robots communicate wirelessly with each other.

When you're ready to get more social with your projects, there are First LEGO Robotics Leagues, LEGO robotics clubs, and LEGO robotics–themed camps. You don't even have to be a kid to enjoy playing with LEGO robotics. I once helped build a team robot at a Google-sponsored booth at the SXSW Interactive festival in Austin, Texas. Part of the challenge even included hacking the Android phone app used as a remote controller for the robot. There wasn't a child in attendance, yet everyone was as excited as a kid in a candy store.

The EV3 is such a wonderful kit for every age, not only because it's a solidly built toy that contains everything you need to get started, but also because you don't have to stick with just the items in the box. The Cubestormer 3 is a world-record-setting Rubik's Cube solver built mainly out of EV3 parts and a Samsung Galaxy S4 phone. One creative 12 year old used the power of an EV3 to build a relatively inexpensive braille printer. Check out Chapter 12, "Extending Play," for more details.

As you can see, the EV3 goes beyond what one could traditionally expect out of a toy. On top of creative play, it offers some great opportunities for problem solving, engineering, and learning while having fun.

This book is intended to help get you started. The projects are all suitable for new users of all ages, whether in a classroom or going solo. Wherever possible, this book explains the why as well as the how. Read the book, tear apart the projects, and improve upon them. There's absolutely no reason why your floor-cleaning robot can't also send you an email to let you know when the floor is clean—or climb stairs.

As you go through the book, because failure can teach you some things that success cannot, you'll occasionally find projects that do not work on the first try. This is mostly intentional, but don't worry—I do explain what went wrong and how to make it right. It's all part of the learning process that, when you've gone cover to cover, will help you become a better builder.

Two versions of the EV3 are available for purchase. Those buying from a toy store will probably have the EV3 Home Edition, whereas those ordering for First LEGO Robotics League or a classroom will tend to have the LEGO Education edition. Don't worry—this book has you covered on both fronts.

What's in This Book

Chapter 1, "What's in the Box?": This chapter goes through the parts and pieces in the EV3 Home Edition, including the included sensors, motors, and test track.

Chapter 2, "What's in the LEGO Education Box?": This chapter goes through the parts and pieces in the LEGO Education set. Even if you don't have this set, you can separately purchase a lot of the parts, so it's a good overview and might give you expansion ideas.

Chapter 3, "Comparing the EV3 and NXT": If you've played with the previous version of LEGO MINDSTORMS, you'll want to check out the differences and improvements in the EV3.

Chapter 4, "Building Your First Bots": This chapter goes over the demo robots available from LEGO and offers a little more insight into the things you should watch out for as you make them.

Chapter 5, "Building the LEGO Education Bots": This chapter goes over the demo models for the LEGO Education set. Build everything from a self-balancing robot boy to a spinning top factory.

Chapter 6, "Hacking What You Have": There's no need to reinvent the wheel when you get started. Take what you learned from the demo models and use it to make something new.

Chapter 7, "Make Your First EV3 Program": This chapter takes the robot you built in Chapter 6 and shows you how to make your first program. This chapter also demonstrates that there are many ways to make the same program.

Chapter 8, "More MINDSTORMS Programming: The Line-Following Robot": This chapter goes more in depth into programming. You'll learn about variables and flowcharting and hopefully gain a little insight into thinking like a programmer.

Chapter 9, "Engineering the Floor-Cleaning Robot": In this chapter, you'll learn how to make an autonomous robot that self-navigates and avoids collisions while cleaning your floor.

Chapter 10, "The Color Magic Card Trick": Rather than making a vehicle, this chapter focuses on the difficult engineering task of getting the robot to deal and identify cards by color.

Chapter 11, "Daisy-Chaining Projects": In this chapter, you'll hook two EV3 robots together and see how they can communicate. You'll also explore wireless communication between EV3 robots.

Chapter 12, "Extending Play": This chapter explores how to install leJOS, an alternative operating system for Java programmers. You'll also look at robotics clubs, robot decoration, and compatible parts from other vendors.

Appendix, "Glossary": The appendix is a glossary of some of the more unusual words you might find in this book.

How to Use This Book

Throughout the book, you'll run across notes and tips.

TIP

Tips are useful pieces of information that will help you avoid a problem or be more efficient.

NOTE

Notes are extra bits of information about the subject. They might mark some great places to study later.

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Building Your First Bots

One of the fantastic things about the EV3 is that great instructions are already available for building all sorts of robots. This chapter looks at the currently available instructions for the LEGO MINDSTORMS home edition set, and Chapter 5, "Building the LEGO Education Bots," explores the instructions available for the LEGO Education set.

You can use this chapter as a reference to see whether you want to try a project, or you could challenge yourself to build along. On top of building along, you can program along. You can choose to download and use the finished EV3 programs as is, or you can follow the mission instructions and build the programs yourself as you go.

Downloading Instructions

Your EV3 home edition set comes with the instructions for the Track3r bot in the written manual. If you lose the printed manual, the Track3r and all other basic instructions are available online at http://www.lego.com/en-us/mindstorms/products/starter-robots/.

You can also get the instructions by downloading the EV3 Home Edition software and launching the "missions," or by using the tablet app available for iPads and Android devices.

NOTE

If you choose to run the included program for your EV3 bot, you should run the mission from within the EV3 desktop software rather than downloading the finished program. On some bots, the downloaded software gives errors for missing blocks.

If you have a tablet, you can enjoy some fantastic 3D building instructions courtesy of LEGO and Autodesk, as shown in Figure 4.1. The LEGO MINDSTORMS 3D Builder app is available either through the Google Play Store or the Apple App Store. The app works on tablets running iOS or Android, but it does not work on phones.

Instructions are shown with 3D animations, and you can spin the model around to see the whole picture. The tablet app is especially helpful for new builders who might be unfamiliar with LEGO's style of instructions.

FIGURE 4.1 When building using the LEGO MINDSTORMS 3D Builder app, each step is animated and rotatable.

The EV3 Starter Robots

Let's go over the basic builds. All the starter robots substitute a *3* for an *e* somewhere in the name, and all of the bots' instructions are broken up into separate missions to either build the bots in stages or add program features.

These pauses between missions allow you to test your robot as you go, since sometimes building a robot from someone else's roadmap can make it confusing to troubleshoot mistakes. The smaller missions also enable you to see how small changes can make big differences in the purpose and function of different robots.

Track3r

The Track3r robot instructions ship with your EV3 Home Edition, and the program to drive your Track3r is already installed on your bot, whether it's the home edition or LEGO Education version. It is the demo program. You can take advantage of that in later chapters by building tanks you can test out before doing any of your own programming. You can also follow along and program your bot to complete the other missions. The programs are relatively simple at this stage and teach you how the programming interface works.

You can build the Track3r in five stages (missions), running the demo software after each build to see how it reacts differently.

TROUBLESHOOTING

Is your bot not moving? The two things you should check when something goes wrong at this stage are your battery levels and port connections.

Low batteries make a bot sluggish, and connecting a sensor or motor to the wrong port means that the program won't tell it to move.

Mission 1

You can see the end-build of Mission 1 in Figure 4.2. The Track3r has blades on one side that spin and an infrared head that doesn't do much other than provide it with good looks. If you launch the demo, you'll see the bot look from side to side by showing different eye graphics, make noise, and drive by itself.

It doesn't go very far. This demo program really is just designed to show you that you made a robot that can run. Hold onto that thought, though. I like to use this same demo program to test other robots I build. It doesn't have to just be a tank bot. I'll show you how this works in Chapter 7, "Make Your First EV3 Program."

FIGURE 4.2 The completed Mission 1 robot.

If you unfold the cardboard test track from your EV3 box (see Figure 4.3), you can actually use this blade and driving motion for a demonstration on your track. Place a tire on the marked area of the track, and the blades will knock the tire around. The robot is self-propelled in this case, and it doesn't vary in its pattern. This is the "mission" part of the first mission. As you build each mission, you'll see a new action you can complete on your test track.

FIGURE 4.3 Use your test track for this mission.

Mission 2

The blades go away for Mission 2, and the Track3r gets a ball shooter, as shown in Figure 4.4. You can place stacked tires on the indicated areas at the end of your test track, and the Track3r will shoot them. It will only shoot them if you put both the tires and the bot in the spots indicated for them on the test track. There is no attempt to sense where things are or compensate for placement differences.

TIP

You should pay attention to how the shooter is constructed in this build because you can reuse the same technique whenever you'd like to build your own shooter.

FIGURE 4.4 The Mission 2 robot with ball shooter.

Mission 3

For Mission 3 you take off the ball shooter and add a gripper, as shown in Figure 4.5. If you place the Track3r and tires on the designated spot on the test track, the bot will grab the tires and place them on another spot.

TIP

This is one of many ways to create a gripping arm. You should pay attention to this build and see whether you can think of ways to improve the gripping power in future builds you create.

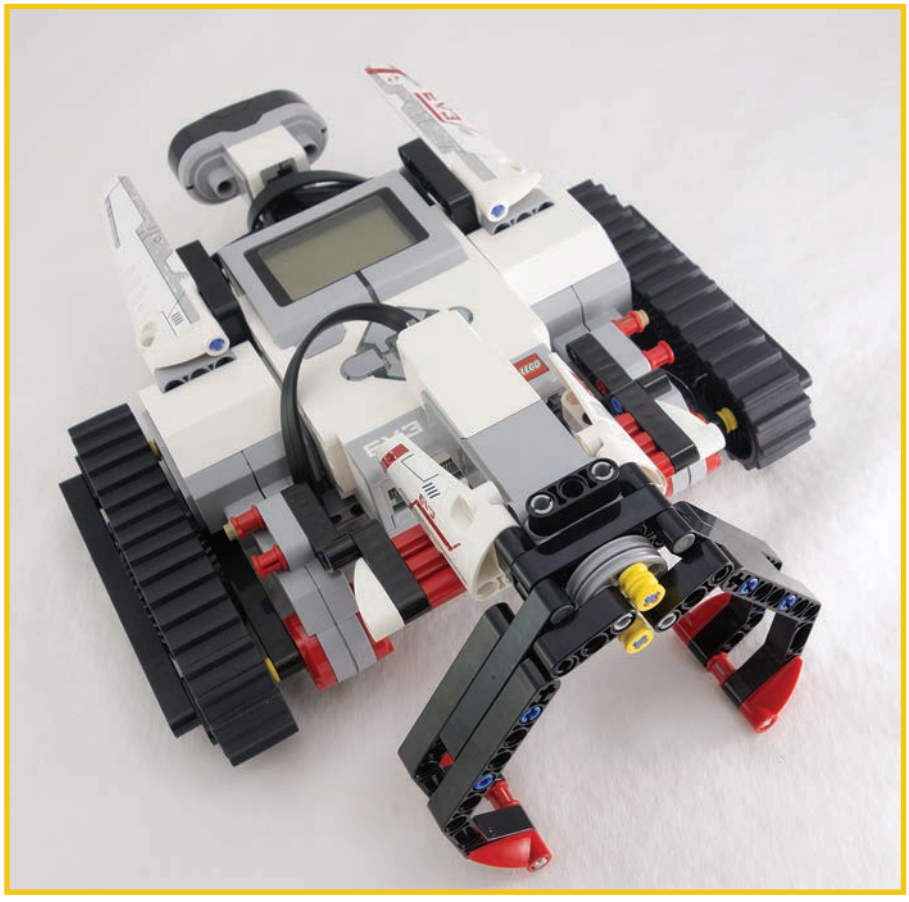

FIGURE 4.5 The gripping style of Mission 3.

Again, the bot makes no attempt to compensate for different conditions, so you must place everything exactly as instructed.

By this point, you should be seeing some real possibilities for your EV3 with just a few variations in engineering and programming. If you can make a tank bot that knocks down items, why not change the "blades" into a broom and make a robot that cleans your floor? If you can program a robot to hit a target, you could tweak the same program to make a robot that avoids those targets.

Sometimes engineering changes necessitate programming changes and vice versa, but not always. As you build a robot, you might go through several iterations to find the most efficient design.

NOTE

One of the best things you can do with these instructions is modify them. One enterprising twelve year old, Shubham Banerjee, modified one of the user-submitted bonus models, the Banner Print3r, to create a low-cost braille printer for the blind.

Mission 4

Figure 4.6 shows the end result of Mission 4. At this stage, you can get rid of the test track and use your bot on a flat surface. A hammer replaces the gripper. This Track3r variation uses the infrared sensor to detect objects, turn around, and try to crush them with the hammer. Not only is this mission a great example of programming with the infrared sensor, it shows you just how versatile the medium motor is. It has now powered a ball shooter, a spinning blade, a gripper, and the hammer.

FIGURE 4.6 The Mission 4 robot gets fancy with its hammer.

Mission 5

Mission 5 brings the Track3r full circle and it gets the whirling blades back, as shown in Figure 4.7, but this mission also adds in the use of the remote control. You now control where the tank goes and whether the blades spin. You could use the Track3r on the test track or on any flat surface.

You might be building to see how the engineering works this time around, but pay attention to the differences in coding, too.

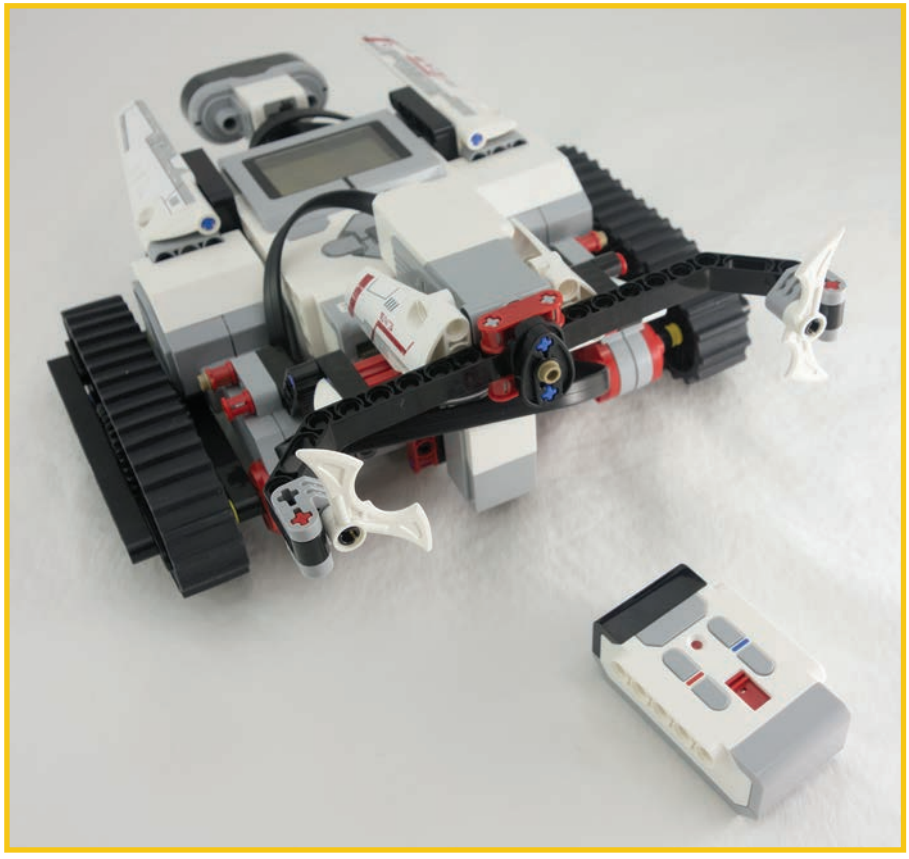

FIGURE 4.7 The Mission 5 robot adds in some whirling blades.

R3ptar

The R3ptar, a robotic snake, is one of my favorite core builds. There are only two building stages for this mission, so it's relatively fast.

Three programs come with the R3ptar instructions:

- Program 1 plays rattling sound effects and moves the bot. It is meant to test your connections on Mission 1, and it's the only program you can run with Mission 1.

- Program 2 uses the infrared sensor to detect and strike at objects near the snake-bot.
- Program 3 enables you to use the remote control to manually control noise and movement.

Mission 1

Mission 1, as shown in Figure 4.8, builds the snake without a head. This is a good time to test your bot, just to make sure you've plugged in everything correctly. Run Program 1 and double-check that the sound effects play and that the robot moves a bit like a snake. If nothing happens, you know you have to go back and troubleshoot your connections and build.

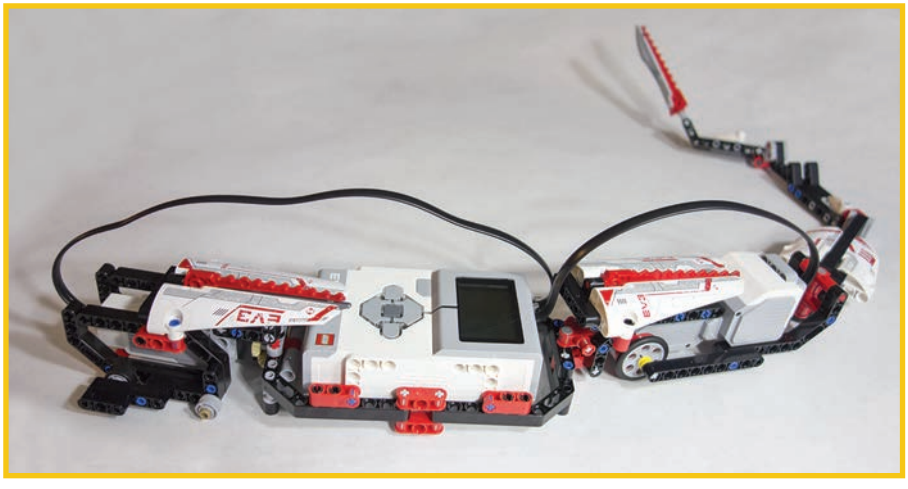

FIGURE 4.8 The headless R3ptar.

Mission 2

Mission 2 completes the bot's look with a head that uses the infrared sensor as eyes and the spiked decorative bushings as teeth (see Figure 4.9).

Make sure you put your robot on a surface with plenty of room, and be sure that you only try Program 2 with people who will appreciate the surprise of having a robot snake strike at them.

CAUTION

Testing this bot with a pet is not only cruel, it could result in damage to your EV3 if an animal becomes surprised and aggressive.

When you run Program 3, you are relying completely on the beacon/remote, so it will no longer strike at anyone unless you press the button to make it happen.

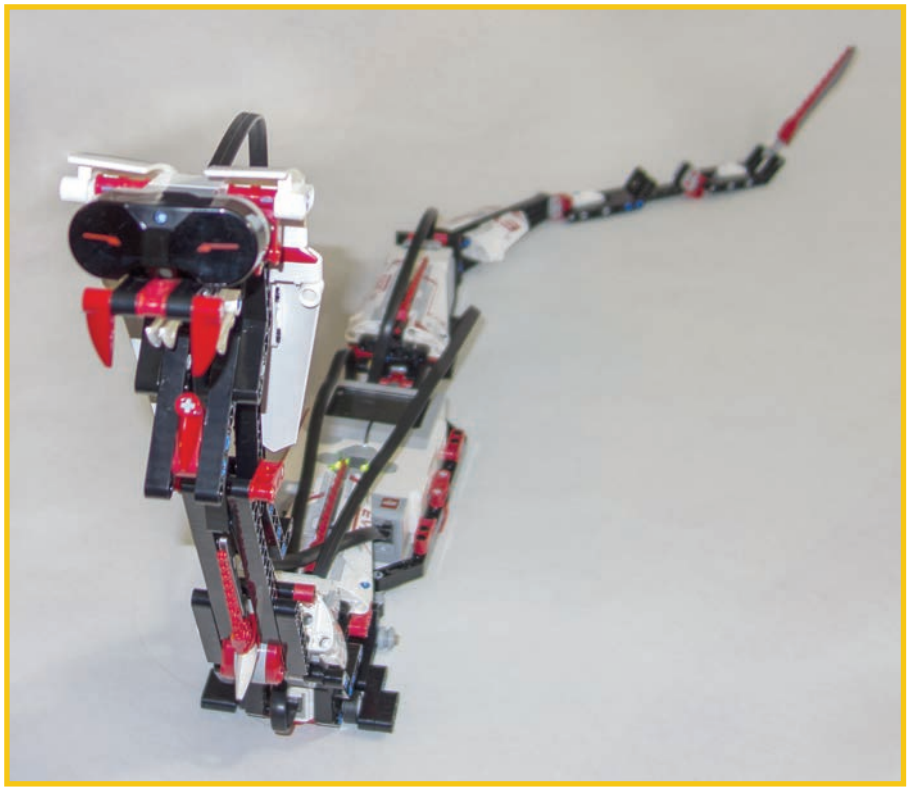

FIGURE 4.9 The completed R3ptor.

TIP

LEGO instructions don't include estimates for the building times, so the easiest gauge for these core models is the number of missions.

Spik3r

Spik3r is a spikey spider or scorpion. The bot works best on large, clean floors, because it moves around and shoots balls. You build this complex bot over five missions, so budget extra time for this one.

Mission 1

Mission 1, shown in Figure 4.10, is just to build and shoot the ball-shooting scorpion tail. This gives you the chance to troubleshoot the shooter before you complete the rest of the build. That's probably a good idea whenever you're building any project, but these demo robots make the concept more concrete.

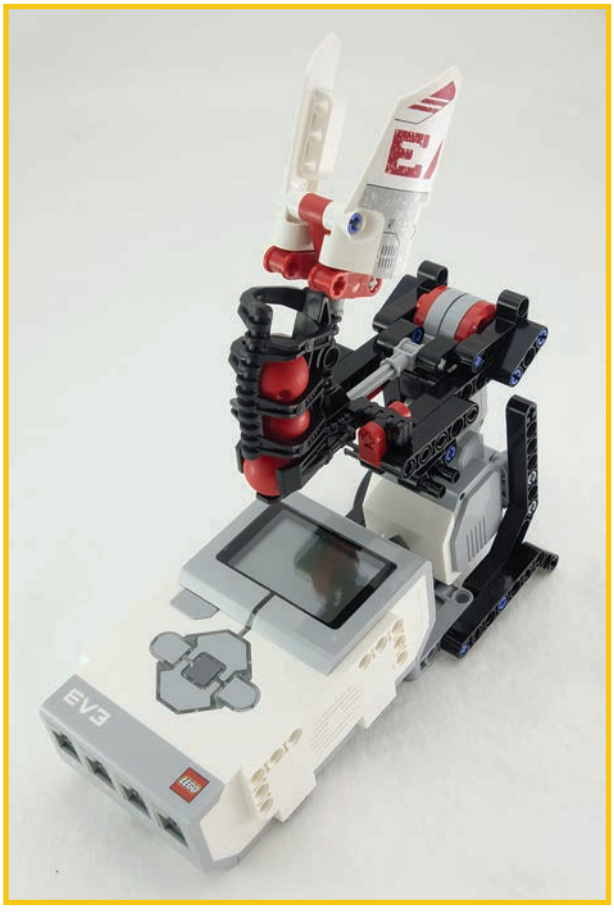

FIGURE 4.10 The completed first mission.

Mission 2

In Mission 2, you add six legs to the bot, as shown in Figure 4.11. The programming mission tests the leg movement along with the ball shooting.

Check out the way the leg build works at this point. There are six legs and only two large motors, so the leg motion has to be divided up in a way that still looks mostly like insect movements and yet allows for the same motor to control multiple legs.

FIGURE 4.11 Mission 2 adds the legs.

Mission 3

In Mission 3, you add pincers to the front of the Spik3r, shown in Figure 4.12. The program uses those pincers to "attack," although at this point the attack is not intelligently guided.

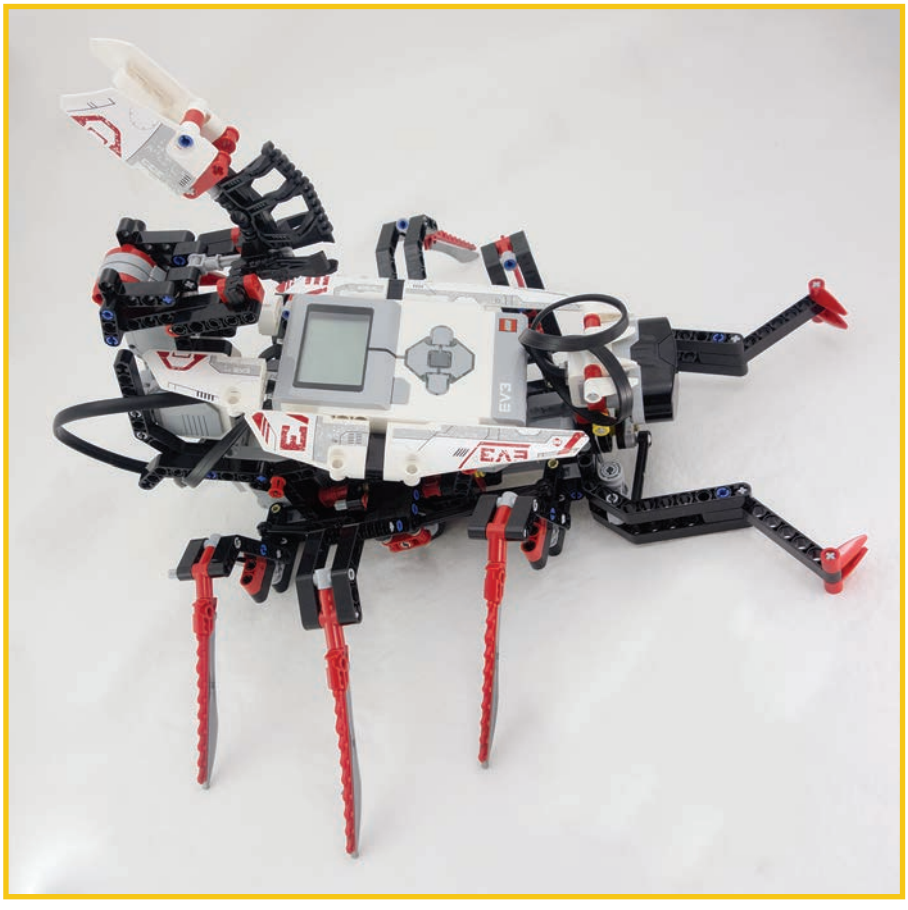

FIGURE 4.12 Mission 3 adds the pincers.

Mission 4

Mission 4 adds infrared sensor control, which searches for objects to attack with the pincers and ball shooting tail. This is an independent action. Figure 4.13 shows the build. Eventually it will search for and attack the beacon.

FIGURE 4.13 Missions 4 and 5 are both pictured here.

Mission 5

Mission 5 adds a cute "bug" created from the remote control, which is also shown in Figure 4.13. The remote in the accompanying programming mission is used as a beacon, so the bot will search for the bug beacon and then shoot it with balls and attack it with pincers. This is the robot all of those missions were working to create.

Ev3rstorm

Ev3rstorm is a punk-rock skating bot built in six missions. Rather than using the usual tank driving motion for treads, this bot has legs that skate along on those treads. This bot is also the most humanoid of the core builds and features prominently on the cover of the EV3 box. You'll use most of the beams with this set, so make sure you don't lose any parts before you start and set aside several hours of building time.

There are six missions in the Ev3rstorm build, which indicates a long build.

TIP

When you test the Ev3rstorm, you'll also want to use a large expanse of clean, hard floor.

Mission 1

Mission 1, as shown in Figure 4.14, is just putting together the legs and tank treads. The program tests the gliding and skating motion in a partial figure-eight pattern. This lets you know if you've hooked everything up correctly.

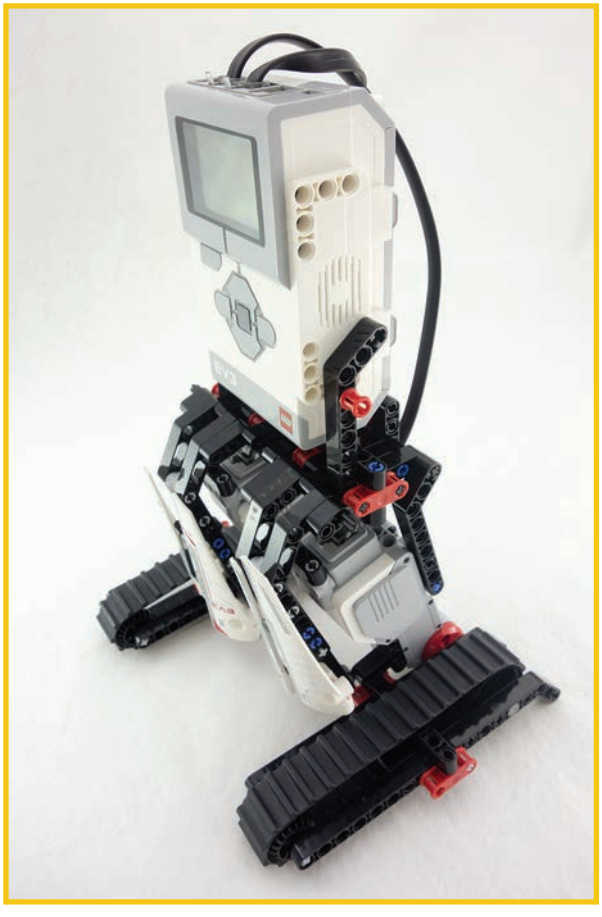

FIGURE 4.14 The skates and not much else.

Mission 2

In Mission 2, your bot starts to look more humanoid (see Figure 4.15) because of the addition of arms and a pincer. The program uses the touch sensor to activate an abbreviated skating pattern. It's no longer the figure eight pattern from the first mission. The arms and pincer are just there for show. You would need an extra motor to make those parts move as well.

FIGURE 4.15 The build starts to look more humanoid.

Mission 3

In Mission 3, you add a blade hand, as shown in Figure 4.16, and this mission enables the use of both the touch sensor and the color sensor to control the bot's motions. The remote will be used later, but this bot does not yet have the infrared sensor in place.

FIGURE 4.16 This robot skates and can be controlled.

Mission 4

Mission 4 adds the infrared sensor as an additional set of eyes (see Figure 4.17). The program uses the infrared sensor, along with the touch or color sensor, to sense and avoid objects in front of it, so you can wave your hand in front of the bot to change its direction.

FIGURE 4.17 Now your robot is mostly assembled.

Mission 5

Now, on Mission 5, you swap out the blade hand for a ball shooter and attempt to shoot targets. I suggest lining up plastic dinosaurs or other toys to see whether your Ev3rstorm can sense and shoot them.

Mission 6

Mission 6, shown in Figure 4.18, is the same build as in Mission 5 but you add a decorated remote beacon, like you did in Mission 5 of Spik3r. The Ev3rstorm will attempt to find and shoot the infrared beacon.

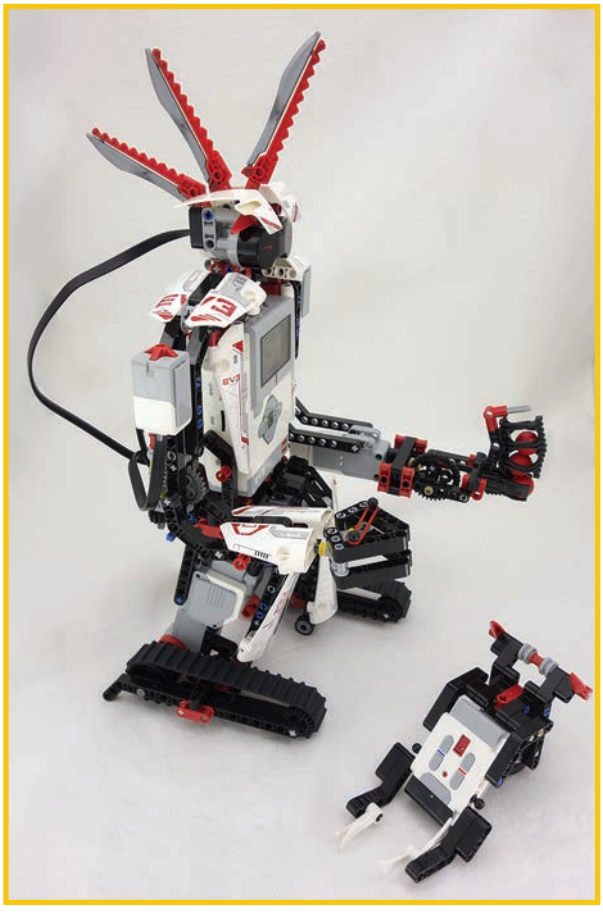

FIGURE 4.18 The robot is the same for Missions 5 and 6. The only difference is the beacon.

Many EV3 fans find this build both incredibly cool and a little frustrating, as it involves building a lot of parts that were swapped out or removed across each of the missions.

Gripp3r

As its name suggests, Gripp3r is a gripping robot. It is humanoid looking with a spikey head and infrared sensor eyes. There's also a slight problem with the build, in that the plastic wing catches on the treads when Gripp3r has lifted an object, meaning that it makes a ratcheting, clicking noise. Fortunately, this is an issue you can safely ignore, as it doesn't seem to damage the robot.

Mission 1

Like the other builds' first missions, you build and test a single part—in this case, the grip handle (see Figure 4.19).

TIP

This is actually great practice for when you want to engineer more complicated parts. Start with the item you think will be most difficult to build. Test it to make sure everything moves well, and then go on to build the rest of the robot around it.

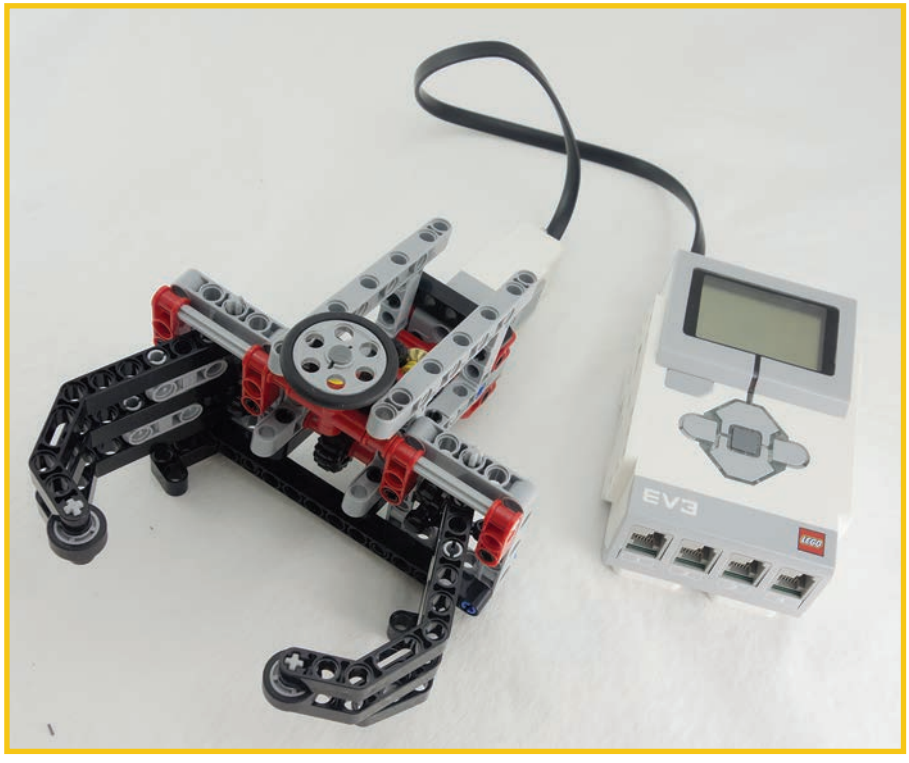

FIGURE 4.19 Test your grip handle before you build the rest of the bot.

Mission 2

In Mission 2, shown in Figure 4.20, you combine the grip you made in Mission 1 with tank treads and add a stacked tire target object for the Gripp3r to grasp.

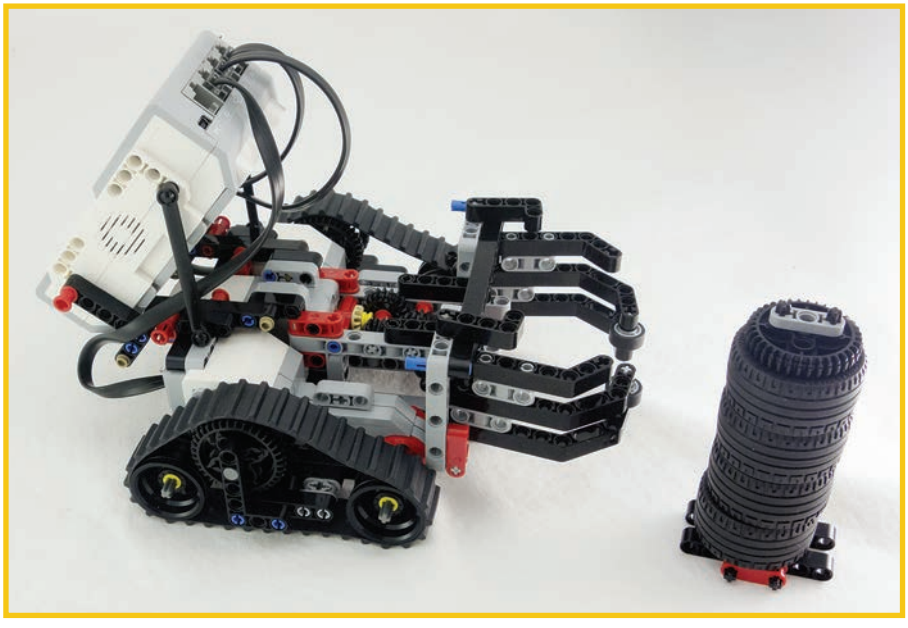

FIGURE 4.20 Here is both the grip handle and the object it will grip.

Mission 3

In Mission 3 you basically complete the Gripp3r build with an infrared sensor and spiked hairdo (see Figure 4.21).

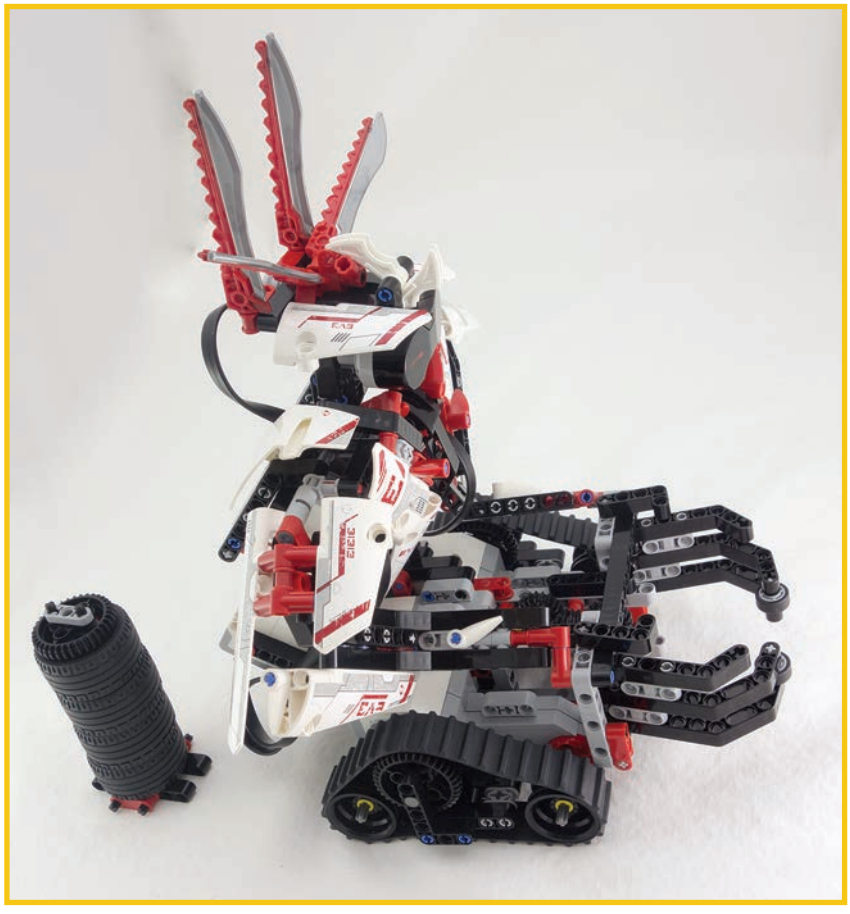

FIGURE 4.21 In this case, the Intelligent Brick actually faces the back of the robot.

Mission 4

Mission 4 adds in remote control (see Figure 4.22). Try having the bot pick up tomato cans or other objects to see how the grip and lift action work.

FIGURE 4.22 After you have built this mission, you can control it by infrared remote.

Bonus Bots

MINDSTORMS beta testers and power users have also created plenty of bonus building instructions. These instructions are available at http://www.lego.com/en-us/mindstorms/products/ev3/31313. These are user submissions. You can download them with your browser or use the More Robots button in the lobby of the EV3 home edition software. I cover this in more detail in Chapter 12, "Extending Play."

Here's a list of the bonus builds available at the time I wrote this book. The list and pictures are available in the appendix in the back of this book.

Banner Print3r

Bobb3e

Dinor3x
El3ctric Guitar
Ev304
Ev3game
Ev3meg
Kraz3
MrB3am
Rac3truck
Robodoz3r
Wack3m

Summary

In this chapter, you learned about the basic models for the LEGO EV3 home edition. Going through the models one at a time to see the end result and get experience building is informative and gives you inspiration for creating and engineering your own robots. The emphasis on missions in these builds sometimes is for testing, but missions often show how quickly and easily you can change a bot's capabilities. The next chapter provides a look at the LEGO Education models as well.

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