Creating Cool MINDSTORMS® NXT Robots

Daniele Benedettelli

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To my brother Alessandro

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About the Author

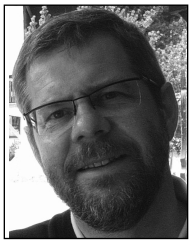
DANIELE BENEDETTELLI appeared in this world on December 2, AD 1984 in Grosseto, the capital city of the beautiful Maremma Toscana. While attending high school, apart from his compulsory studies, his main passion was writing music and playing the piano, a passion to which he devoted his childhood. When he was not playing the piano, you could find him playing with LEGOs.

This last passion took a backseat during his "dark age of LEGO," when real-life interests got the better of building plastic creations. In 2000, Daniele scraped enough savings together to get the LEGO MINDSTORMS Robotics Invention System, and from that moment on, a new way of relating to LEGO began: his adult career in the LEGO community started! In 2006, he got a Bachelor of Science degree cum laude in Computer Engineering (Automation concentration) from the University of Siena with a thesis whose approximately translated title is "LEGO MINDSTORMS–based mobile robots team." A toy—a destiny, we could say. Now he's studying for a Master of Science degree in Robotics and Automation at the University of Siena.

In 2006, he was selected by The LEGO Group as member of the MINDSTORMS Developer Program (MDP), and in 2007 as one of MINDSTORMS Community Partners (MCP).

2007 was a turning point for Daniele. He gave birth to a LEGO NXT robot that can solve automatically any 3×3 Rubik's Cube in less than a minute. This robot is the mechanical part of the project called the LEGO Rubik Utopy. The world has gone crazy over this wonderful contraption. His activity with LEGO on the NXT line is continuing now with the group called the MINDSTORMS Community Partners 2.0.

About the Technical Reviewer



Since 1999, **CLAUDE BAUMANN** has taught advanced LEGO MINDSTORMS robotics in after-school classes and maintains the related widely known web site `http://www.convict.lu/Jeunes/RoboticsIntro.htm`. He participated in beta testing of the ROBOLAB software that originated at Tufts University. He also has been in charge—in collaboration with Professor Chris Rogers— of the creation of ULTIMATE ROBOLAB, a cross-compiler environment that allows graphical programming of RCX firmware, and of a unique RCX self-replicating program (also called a "virus"). Claude has been the assessor of various high-school robot projects (among which is the famous LEGO humanoid robot GASTON). He is the author and coauthor of several related articles and conference presentations, and he was the technical reviewer of *Extreme NXT: Extending the LEGO MINDSTORMS NXT to the Next Level* by Michael Gasperi et al. (Apress, 2007). In 2004 and 2005, he was guest speaker at the annual ROBOLAB Conference in Austin, Texas. He's married and has three children, is the director of a boarding institution in Luxembourg, and is the radio amateur LX1BW.

Acknowledgments

I always find reading a book's Acknowledgments section interesting: it is a sort of back stage, where you can get an idea of the work hidden behind these pages.

As is customary, let me first thank all my family. In particular, a thanks goes to my father for the support and inspiration through the development process of the robotic creations in this book. Also, the one-way chats with my mother led me to think aloud and solve many tricky building and programming issues: thanks to her for listening to my incomprehensible ponderings! Thanks to my brother Alessandro, talented guitarist, who spurred me on with suggestions such as "Go and do something serious, instead of playing!" However, this English translation is just a pale rendering of the Italian "*Ma vai a lavoro!*"

Now, I have to thank and acknowledge a lot of people who helped me, more or less directly, during the creation of this book. Forgive me if one name happens to appear before another. Keeping the list in chronological order is as good a rule as another.

I wish to thank Mario Ferrari, major author of well-known LEGO books, who guided my first steps in the LEGO community, since the LEGO Fest where I met him and the members of ITLUG, the Italian LEGO Users Group.

I wish to acknowledge the great work of John Hansen, programmer and MDP/MCP fellow. He is the creator of Not eXactly C (NXC), the powerful textual programming language for the NXT that has been used for the robots of this book. Also, he wrote a number of utilities to interface the LEGO bricks to the computer. One above all, Bricx Command Center (BricxCC), is the environment you'll use to program your robots in NXC. Thanks, John. You gave me the words to instruct my robots!

In this book, you'll enjoy hundreds of detailed building instruction step images, the result of many, many hours of hard work that's not only mine. In fact, the LDRAW system, which I used to draw the 3D CAD models of my robots, is powered by many people who made up the LEGO elements' virtual counterparts. A huge thanks go to all the authors of the parts and of the software: talented people who built up the LDRAW system as we know it today. In particular, I wish to thank the ones who designed the NXT parts you'll see in the following pages: Steve Bliss, Matthias Paul Scholz, and Marc Klein. I myself contributed a little bit, making an early version of the Ultrasonic Sensor front shell.

Philippe Hurbain and Kevin Clague are among those parts' authors, and deserve special thanks. Philippe Hurbain (Philo) is another MDP member and Apress author, who took priceless time to design great-looking CAD versions of most parts of the NXT system. Above all, his masterpieces are the NXT brick, the Sound Sensor, the servomotors, and the BIONICLE claw weapon.

Kevin Clague—MDP member, book author, and creator of many inspiring LEGO bipeds—wrote some really useful programs that I used to assemble the layouts for the building instructions: LEGO Publisher (LPUB) and LEGO Synth, a LEGO bendable parts synthesizer, used to draw the flexible cables. He helped me in learning LPUB, during a period of testing and debugging of the software. Kevin, thank you for your great patience!

Speaking of patience, another person I really want to thank is Claude Baumann, the technical reviewer of this book. My gratitude goes to him for many reasons. First, he believed in my Rubik Solver robot, and invited me, in Luxembourg, to The Science Circus. There I had occasion to see his skill for instruction and passion for teaching. I am glad he accepted the position of my technical reviewer. Apart from the mere technical reviewing of the programs and robots in this book, I wish to thank him for having tried to teach me how to teach. I say "tried" because I was not the ideal pupil! Anyway, your words of advice are precious. Thank you.

Thanks also to the Apress staff, whose names were reported a few pages ago. In particular, thanks to editor Gary Cornell: my brief e-mail was enough for him and his staff to believe in this book that did not exist at that time, except in my head. So, Apress, thanks for having believed in the robots shown on my web page and the material for a book! Thanks to Jeffrey Pepper, lead editor. Thanks to Beth Christmas, my kind project manager, who kept order in my (sometimes) messy material submissions, and John Vacca for his work in getting the "English" into English. On the writing side, thanks to Susannah Davidson Pfalzer, copy editor, who made my style fluent and grammar-examination–proof!

The photos of JohnNXT and the NXT AT-ST robots on the book cover are by Benjamin Maier, professional photographer and friend of mine. I hope he enjoyed spending his time finding my robots' best side and lighting direction. Anyway, I won't steal his time again, so he can direct another feature film—then I'll have the occasion to compose another soundtrack. Thanks, Ben!

I conclude with a little note of regret, while I thank Narendra Sakharam Gaonkar, my native-English-speaking friend and linguistic consultant. Narendra, if only one of the epic and far-reaching alternative titles we conceived for this book had been accepted!

Introduction

You are a LEGO MINDSTORMS NXT owner, aren't you?

If you have this book in your hands, maybe you've already tried (and maybe exhausted) the possibilities offered by the NXT retail set, and the building and programming guides. If not, I recommend that you use those official LEGO guides to start. So, you should have at least a basic idea of what a robot is—otherwise I suspect that you would not even have thought about reading this book!

I began to think of this book as a way to introduce LEGO users to some advanced topics of robotic programming, always keeping it simple, without scaring anyone. In the few theoretical discussions you'll find, you won't have time to get bored: all the theory is explained in order to understand the practice better.

This book is divided into two parts. With the first, I want to break away from the same boring wheeled robots—there are too many of them around. We're used to vehicles; we want to move on legs! So, this part is devoted to walking robots—bipeds in particular. In Chapter 1, I tried to summarize the state of the art for LEGO bipedal walkers. Subsequent Chapters 2, 4, and 5 present three biped robots in order of complexity. Chapter 3 is the only real theoretical chapter, where you learn the finite state machine software technique to give your robot personality and autonomous behaviors. In Chapter 6, the NXT Turtle is described. This is a quadruped robot, featuring a funny autonomous behavior.

The second part is about wheeled robots. I could not write a book without them. That's also because, apart from the Mine Sweeper (an object-collecting vehicle), the other wheeled robot is the great JohnNXT: a replica of Johnny 5, robot star from the *Short Circuit* 1980s movies. I haven't counted the number of people who directly contacted me to ask for JohnNXT instructions, but they are in the hundreds. So, JohnNXT could not be missing from this book.

Except for Chapters 1 and 3, the other chapters containing a robot are organized as follows. At the beginning, the robot is introduced and its capabilities are described. Then, the Not eXactly C (NXC) programs to implement those capabilities are reported and described in detail. Various arguments are deepened, taking advantage of the occasion to discuss programming techniques that arise over and over. The building section is at the end of the chapter. This placement avoids chopping the reading flow in two. The building instructions are introduced first with a detailed bill of materials; then, each step is commented to help with the building. At the end of some chapters, you might find a few exercises, meant to be inspirational cues.

Who Is This Book For?

Mainly, this is a book that should entertain everyone. If the reading will add something to your knowledge, so much the better! So, this book is for the following:

- Those from 6 to 106 years old, wishing to build cool LEGO robots to have fun, without being expert programmers.
- Those who want to build a Johnny 5 replica (more than you might think!).
- Those who need inspiration for their own new creations.
- Those who are tired of exploring the equivalent area of hundreds of computer screens occupied by the graphical NXT-G block programs, who want to change radically the way to program the NXT.
- Those wishing to learn a textual C-like programming language without getting frustrated by complicated useless programs for novices, or bored by abstract exercises. Every program in this book produces visible results.
- Those wishing to learn new programming techniques.

Children, remind your parents that LEGO MINDSTORMS is not their exclusive toy. Ask them for help if you want—you'll have a great time! Parents and grandparents, you can use this book as an excuse to start playing seriously with LEGO robots, while spending time with your kids and grandkids. But let go of that NXT brick—let 'em play too!

What You Need to Use This Book

You can build all the robots using the parts from a single LEGO MINDSTORMS NXT retail set (code number 8527), except the last big one, JohnNXT, and the remote control. So you can enjoy the building and relax—you won't find out that you're missing a needed part when you're a step from the end! If you plan to build and control JohnNXT remotely, I suggest you find all the parts first: you need three NXT sets, and many other extra parts, all listed in the appropriate bills of materials in Chapters 8 and 9.

Then you need a computer to write and send the programs to your NXT robots. The software I used runs on Windows. Mac and Linux releases of the NXC compiler exist, but you'll have to find an alternative Integrated Development Environment (IDE) for the handy Bricx Command Center (BricxCC).

To enjoy this book, you do not have to be a programmer, although it can help you learn the basics to become a programmer. *You can also follow the building instructions and then download the programs provided to your robots, without having to write a single line of code.*

About the software: you should already have the NXT-G program provided by LEGO in your retail set. The other software is the BricxCC IDE and the NXC compiler, both downloadable from `http://bricxcc.sourceforge.net/` and `http://bricxcc.sourceforge.net/nbc/`.

When facing a new programming topic, I recommed that you keep an eye on the complete *Not eXactly C (NXC) Programmer's Guide* by John Hansen, which you can download from

http://bricxcc.sourceforge.net/nbc/nxcdoc/NXC_Guide.pdf. To get an idea of what the NXC language looks like, you can also read the tutorial I wrote, *Programming LEGO NXT Robots using NXC*. This paper is available for free at http://bricxcc.sourceforge.net/nbc/nxcdoc/NXC_tutorial.pdf.

Source Code and Extras for This Book

You can download the complete source code for the programs from the Source Code/Download area on the Apress web site, at http://www.apress.com. Also, you can visit the web site http://robotics.benedettelli.com.