

Advanced NXT

The Da Vinci Inventions Book



Matthias Paul Scholz

Advanced NXT: The Da Vinci Inventions Book

Copyright © 2007 by Matthias Paul Scholz

All rights reserved. No part of this work may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or by any information storage or retrieval system, without the prior written permission of the copyright owner and the publisher.

ISBN-13 (pbk): 978-1-59059-843-6

ISBN-10 (pbk): 1-59059-843-1

Printed and bound in the United States of America 9 8 7 6 5 4 3 2 1

Trademarked names may appear in this book. Rather than use a trademark symbol with every occurrence of a trademarked name, we use the names only in an editorial fashion and to the benefit of the trademark owner, with no intention of infringement of the trademark.

LEGO® and MINDSTORMS® are trademarks or registered trademarks of the LEGO Group in the United States and other countries. Apress, Inc., is not affiliated with the LEGO Group, and this book was written without endorsement from the LEGO Group.

Lead Editors: Matthew Moodie, Jim Sumser

Technical Reviewer: Jim Kelly

Editorial Board: Steve Anglin, Ewan Buckingham, Gary Cornell, Jonathan Gennick, Jason Gilmore,

Jonathan Hassell, Chris Mills, Matthew Moodie, Jeffrey Pepper, Ben Renow-Clarke,

Dominic Shakeshaft, Jim Sumser, Matt Wade, Tom Welsh

Project Manager: Kylie Johnston

Copy Edit Manager: Nicole Flores

Copy Editor: Jennifer Whipple

Assistant Production Director: Kari Brooks-Copony

Production Editor: Laura Cheu

Compositor: Susan Glinert Stevens

Proofreader: Lori Bring

Indexer: Carol Burbo

Artist: April Milne

Cover Designer: Kurt Krames

Manufacturing Director: Tom Debolski

Distributed to the book trade worldwide by Springer-Verlag New York, Inc., 233 Spring Street, 6th Floor, New York, NY 10013. Phone 1-800-SPRINGER, fax 201-348-4505, e-mail orders-ny@springer-sbm.com, or visit <http://www.springeronline.com>.

For information on translations, please contact Apress directly at 2855 Telegraph Avenue, Suite 600, Berkeley, CA 94705. Phone 510-549-5930, fax 510-549-5939, e-mail info@apress.com, or visit <http://www.apress.com>.

The information in this book is distributed on an “as is” basis, without warranty. Although every precaution has been taken in the preparation of this work, neither the author(s) nor Apress shall have any liability to any person or entity with respect to any loss or damage caused or alleged to be caused directly or indirectly by the information contained in this work.

The source code for this book is available to readers at <http://www.apress.com> in the Source Code/Download section.

To the memory of Stanislaw Lem (1921–2006)

Contents at a Glance

About the Author	xi
About the Technical Reviewer	xiii
Acknowledgments	xv
Preface	xvii
■ CHAPTER 1 Introduction	1
■ CHAPTER 2 A 3,000-Foot Look at NXT Programming Environments	29
■ CHAPTER 3 The Armored Car	55
■ CHAPTER 4 The Catapult	107
■ CHAPTER 5 The Revolving Bridge	167
■ CHAPTER 6 The Aerial Screw	227
■ CHAPTER 7 The Flying Machine	277
■ CHAPTER 8 Outlook: What NXT?	331
■ APPENDIX A Installation and Configuration of the Programming Environments Used in the Book	341
■ APPENDIX B Leonardo's Letter of Application to the Duke of Milan	357
■ APPENDIX C Glossary	359
■ APPENDIX D Bibliography	363
■ INDEX	365

Contents

About the Author	xi
About the Technical Reviewer	xiii
Acknowledgments	xv
Preface	xvii
■ CHAPTER 1 Introduction	1
An Invention-Driven Tour Through the Life of Leonardo da Vinci	2
Renaissance Man	2
Five Designs	4
The LEGO MINDSTORMS NXT	15
Hardware	16
Software	23
The NXT Community	25
The MINDSTORMS Developer's Program	25
LEGO.com MINDSTORMS Community NXT	25
MINDSTORMS Education NXT	25
The NXT STEP	26
nxtasy.org	26
mynxt.matthiaspaulscholz.eu	26
Summary	27
■ CHAPTER 2 A 3,000-Foot Look at NXT Programming Environments	29
LEGO MINDSTORMS NXT Software	30
NXT-G	30
IDE	35
Example Program Snippets	39
RobotC	42
IDE	44
Example Program Snippets	46

NXC	47
IDE	48
Example Program Snippets	50
pbLua	51
Example Program Snippets	52
leJOS NXJ	52
Example Program Snippets	53
Summary	54
CHAPTER 3 The Armored Car	55
Historical Background	55
Special Challenges	57
Interpreting the Design	57
Building the Gearing Mechanism	58
Building the Armored Car	59
Programming the Armored Car	97
LEGO MINDSTORMS NXT Software	98
RobotC	99
NXC	100
pbLua	101
leJOS NXJ	103
Summary	105
CHAPTER 4 The Catapult	107
Historical Background	107
Hardware Challenges	109
The Double Leaf Spring	109
The Crank Mechanism	109
Building the Catapult	111
Programming the Catapult	147
LEGO MINDSTORMS NXT Software	149
RobotC	152
NXC	155
pbLua	157
LeJOS NXJ	161
Summary	165

CHAPTER 5	The Revolving Bridge	167
	Historical Background	167
	Hardware Challenges	168
	Building the Revolving Bridge	169
	Programming the Revolving Bridge	210
	LEGO MINDSTORMS NXT Software	211
	RobotC	214
	NXC	217
	pbLua	219
	leJOS NXJ	222
	Summary	226
CHAPTER 6	The Aerial Screw	227
	Historical Background	227
	Hardware Challenges	231
	Building the Aerial Screw	231
	Programming the Aerial Screw	260
	LEGO MINDSTORMS NXT Software	262
	RobotC	264
	NXC	267
	leJOS NXJ	268
	pbLua	272
	Summary	275
CHAPTER 7	The Flying Machine	277
	Historical Background	277
	Hardware Challenges	278
	Building the Flying Machine	280
	The Wires That Lower the Wings	306
	The Wires That Lift the Wings	307
	Building the Remote Control	309
	Programming the Flying Machine	318
	LEGO MINDSTORMS NXT Software	319
	NXC	324
	Summary	329

CHAPTER 8	Outlook: What NXT?	331
	Enhancing the Five Robots	331
	The Armored Car.....	331
	The Catapult	332
	The Revolving Bridge	332
	The Aerial Screw.....	333
	The Flying Machine	333
	Remotely Controlling the Robots	333
	Making Other Inventions of Leonardo with LEGO	334
	The Theater Stage for Orpheus.....	335
	The Canal Excavation Machine	335
	Recommended Web Sites	336
	Web Sites on Leonardo da Vinci	336
	Sites on LEGO MINDSTORMS NXT	337
	Recommended Books	338
	LEGO MINDSTORMS NXT: The Mayan Adventure.....	338
	The LEGO MINDSTORMS NXT Idea Book.....	339
	Maximum LEGO NXT: Building Robots with Java Brains	339
	Leonardo's Machines: Da Vinci's Inventions Revealed.....	339
APPENDIX A	Installation and Configuration of the Programming Environments Used in the Book	341
APPENDIX B	Leonardo's Letter of Application to the Duke of Milan	357
APPENDIX C	Glossary	359
APPENDIX D	Bibliography	363
INDEX		365

About the Author

■ **MATTHIAS PAUL SCHOLZ** has a degree in mathematics obtained at the University of Bayreuth, Germany, and works presently as a system engineer. He has held IT-related positions in various companies in Germany over the past 12 years, specializing in model-driven development and distributed environments. He has been an active member of the LEGO MINDSTORMS community since 2000. Scholz was one of the developers of the open source leJOS platform for the RCX, took part in the LEGO MINDSTORMS Developer Program, and is presently one of the 20 members of the LEGO MINDSTORMS Community Partners Program. Furthermore, he is one of the contributors to the popular The NXT STEP blog and maintains the German-language sister blog, Die NXTe Ebene. His own MINDSTORMS NXT-related web site is at <http://mynxt.matthiaspaulscholz.eu>.

About the Technical Reviewer

■ **JIM KELLY** is a freelance technical writer in Atlanta, Georgia. He obtained a bachelor's degree in English from the University of West Florida and a bachelor's degree in industrial engineering from Florida State University. He has been writing and editing for more than nine years. He is currently a member of the LEGO MINDSTORMS Community Partners Program and works with other members to improve and test the MINDSTORMS NXT and other products. Jim is the author of the Apress books *LEGO Mindstorms NXT: The Mayan Adventure* and *LEGO Mindstorms NXT-G Programming Guide*.

Acknowledgments

First of all, I would like to thank my most amiable wife for her support and patience with all the evening, late-night, and weekend hours I spent on the book in the past months.

Special and very cordial thanks go to Jim Kelly who encouraged me to write this book, opened doors for me, and not only provided warmhearted guidance and indispensable advice but also acted as a tech editor for the book.

Also, I'd like to thank all the other aficionados out there whose commitment and mad rapture for LEGO MINDSTORMS NXT filled me with the energy to complete all the work for the book. In particular, I'd like to mention Steven Canvin from LEGO, Maureen Reilly from NXTLOG, Brian Davis, Steve Hassenplug, Philo, and The NXT STEP gang. Thanks also to the guys from the leJOS NXJ project, John Hansen for NXC, Ralph Hempel for pbLua, and Daniele Benedettelli and Lukas Probst for their tutorials. These people are only a small section of all the enthusiastic LEGO weirdos that form a bustling community I'm proud to be a part of. Please bear with me if I forgot to name someone who particularly deserves it.

I am amazed and grateful for the work done by the production team for this book, in particular Kylie, Jennifer, and Laura from Apress, who did a prodigious job, and I'd like to voice my particular gratitude for being that dedicated and so very patient with me.

Preface

Robots have been a source of fascination to me since my childhood. That was during the time of the first *Star Wars* trilogy, with very humanlike robots appearing on the screen, such as C-3PO, who still reminds me of some friends of mine, and not so humanlike others, such as R2-D2 (who nevertheless also reminds me of some people I know). There were the books of Stanislaw Lem and Douglas Adams that discuss the philosophical questions related to the creation of artificial beings. Do androids dream of electric sheep? I still wonder.

Yet all my attempts to build something similar on my own failed. The gizmos I'd assembled from wood and plastic not only looked strangely different from the ones I had in mind, but also didn't do anything (besides fall apart frequently). The time was not ripe for building robots of your own, unless you had a degree in electronic engineering, high soldering capabilities, and a well-endowed bank account to acquire all the special electromechanical parts required.

This all changed dramatically when in 1998 the LEGO Group released the LEGO MINDSTORMS system. At once it was possible to build robots with a technology that I and almost everyone else I knew was used to since childhood: LEGO bricks. In fact, I considered LEGO to be only a toy then and my trunk full of bricks had long ago changed possession to my little brother. But it didn't take long to realize the potential of the new product line. I was even more surprised to find out that there was a MINDSTORMS community out there that to a large part was composed of people of my age, my professional IT background, and my interest in technics, in particular in robotics. Consequently, I bought some of the kits and expansions and indulged in the open source movement that was rapidly growing and bustling with energy. That is, I became one of the developers of the leJOS project, dedicated to providing a Java implementation for the MINDSTORMS RCX Brick.

So the millennium went by with creating robots and trying to overcome the limitations of the RCX, whose technical parameters were already outdated in 1998. An update was overdue, but instead, the kits were beginning to disappear from the shops and it seemed that LEGO was resting on the laurels of MINDSTORMS, which had developed into the best-selling product in the company's history.

Fortunately that wasn't the case at all.

In 2005, rumors began to spread that a successor to the RCX was to be expected. Indeed, LEGO announced the MINDSTORMS Developer Program (MDP) and asked for applications. I instantly jumped in—without much hope—as virtually everyone I knew in the community did the same. How great, though, was my joy when I received a confirmation that I was to be one of the blessed 100? As a matter of fact, I didn't believe it in the beginning, suspecting that it was just a cruel joke by my friends.

It wasn't, and what was to follow were months of fun, devotion, and creative energy. The days had not enough hours and the kits not enough parts to implement all the ideas that were appearing in my head and in those of the most interesting and different people I've met in the program. Well, one needs to bring home the bacon, but I realized then how tedious your (otherwise satisfying) everyday job is able to appear when you long to race home and complete the time machine you are tinkering with.

One of the ideas that arose rather early was to combine my NXT-related activities with another topic of interest to me—medieval history. It was only a small step to notice that the mechanical works of one of the greatest engineers ever, Leonardo da Vinci, would suit the subject tremendously well. However, I never dreamt of really writing a book on it, and most likely it wouldn't have come

into being if Jim Kelly—whom I’m proud to be connected to by the MDP, the blog we both write for, and last but not least, the books in this MINDSTORMS series—hadn’t encouraged me to do so.

Hence, here it is. I hope you enjoy it.

Who This Book Is For

This book is about building quite complex LEGO NXT robots with a lot of different parts. You will learn techniques to master certain challenges in building real-world gadgets with LEGO and how to make best or at least good use of special parts that are contained in the NXT kit or in other ones. You also should get a feeling for how to transform contraptions from the “real” world into LEGO devices and how to use the motors and various sensors the NXT kit provides.

That said, some of the robots are rather sophisticated and comprise a lot of different parts that are arranged in a sometimes complicated manner. Therefore, absolute beginners who do not feel at least basically at ease with LEGO TECHNIC and studless building might prefer to make themselves familiar with these topics before trying to tackle the robots introduced in this book.

As for the software, a fundamental understanding of the basic principles of programming is recommended. I introduce five different environments for creating and running programs in the NXT, where almost each one is based in a particular development paradigm. It goes without saying that there’s always the option of concentrating on one single environment and leaving the others out; but even so, some experience with the programming paradigm in question—for instance, with object-oriented programming in the case of leJOS—might prove useful. Also, when it comes to the software, programming newbies might wish to address some tutorials before implementing the programs in the book.

For the NXT environments used in the book, though, no previous knowledge is required. I explain in detail not only their installation and configuration, but also the language constructs, which are displayed by example in a step-by-step manner.

In the end, you should be familiar with the strategies to implement standard challenges for NXT robots in the different languages and have an overview of the options available for programming the NXT and know which one best fits your background and taste.

How This Book Is Structured

This book is organized around chapters that recreate five inventions of Leonardo da Vinci using LEGO. Each of these chapters consists of the following:

- A lecture on the historical background
- A discussion of the hardware challenges the invention imposes on a LEGO model and the solution
- Complete step-by-step building instructions
- Programming instructions for each of the five programming environments the book uses

Chapter 1: Introduction

This chapter consists of a tour through Leonardo’s life and five of his most famous inventions to be built with LEGO. It also introduces the NXT and its components and provides a glimpse of the NXT community and some of its most prominent sites.

Chapter 2: A 3,000-Foot Look at NXT Programming Environments

This chapter discusses the five different programming environments used in this book: the official LEGO MINDSTORMS NXT Software, RobotC, NXC, pbLua, and leJOS NXJ. It focuses on those that allow running programs directly on the Brick—autonomous robots rather than those confined to remote control from an external device such as a computer or a cell phone.

Chapter 3: The Armored Car

This chapter is the first robot chapter. It deals with Leonardo's design of an armored car, a machine like today's military tank. Like the following four chapters, it provides a historical background, a discussion of the LEGO hardware challenges and their solutions, the building instructions, and the programming of the robot with five different programming environments.

Chapter 4: The Catapult

This chapter introduces one of the catapults Leonardo designed and shows how to build it with LEGO. You will encounter the device he invented to set up kinetic energy and the touch sensor.

Chapter 5: The Revolving Bridge

This chapter shows how to build Leonardo's revolving bridge with LEGO. You will gain insight into motor synchronization and learn how to make use of the ultrasonic sensor.

Chapter 6: The Aerial Screw

This chapter presents a LEGO implementation of Leonardo's aerial screw, also—but misleadingly—known as the “helicopter.” It's an introduction to mimicking curved structures and to the usage of the light sensor.

Chapter 7: The Flying Machine

This chapter showcases another machine invented by Leonardo for the purpose of flying and how to build it with LEGO. Its “flapping wings” make it different from the aerial screw. You will learn how to use wires to run mechanical parts and to remotely control a NXT robot.

Chapter 8: Outlook: What NXT?

This is a discussion of the conceivable steps the reader may take from here. It discusses possible refinements of the preceding five robots and the possibility of remotely controlling them. It sheds some light on other inventions of Leonardo's that might be created with LEGO, and finally introduces some web sites and books recommended for further reading.

Appendixes

This book contains four appendixes. The first provides step-by-step guides to the installation and configuration of the five different programming environments in this book. The second contains a copy of Leonardo's letter of application to the duke of Milan that is mentioned frequently in the book. The final two appendixes are a glossary and a bibliography.

Prerequisites

To complete the programming examples in the book, you will need five different programming environments for the NXT. The first one is contained in the retail version of the NXT kit, while the others are available on the Internet, either for free or as trial versions. Appendix A provides all the information you need to download, install, and configure them for this book.

Downloading the Code

The source code for this book is available to readers at the Apress web site at <http://www.apress.com> in the Source Code/Download section. You can also check for errata and find related titles from Apress.

Additional material related to the book such as updates, videos and more can be downloaded from my web site at <http://mynxt.matthiaspaulscholz.eu>.

Contacting the Author

If you are eager to contact me for feedback, questions, or suggestions, feel free to use the contact page on my web site at <http://mynxt.matthiaspaulscholz.eu/contact>. I always try to respond to any approach by a reader as soon as possible.