

contents in detail

| | |
|--|--|
| introduction | xix |
| playing without a computer | xix |
| whom is this book for? | xix |
| what do I need to use this book? | xix |
| the EV3 software | xix |
| the structure of this book..... | xx |
| the companion website | xx |
| let's start already!..... | xx |
| | |
|  comic: the EV3L scientist's apprentice..... | 1 |
| continued | 15, 45, 66, 84, 94, 101, 129, 175, 189, 228, 247, 293, 307, 358, 380, 402 |
| | |
| 1 | |
| your LEGO MINDSTORMS EV3 set..... | 5 |
| the studless way of building | 5 |
| studless vs. studded: the structural differences | 5 |
| naming the pieces | 6 |
| beams | 6 |
| connectors | 8 |
| <i>crosses and holes</i> | 9 |
| gears | 11 |
| wheels, tires, and treads | 12 |
| decorative pieces | 13 |
| miscellaneous pieces | 13 |
| electronic pieces | 13 |
| the differences between the EV3 retail and education sets | 14 |
| conclusion..... | 14 |
| | |
| 2 | |
| building ROV3R..... | 17 |
| base module..... | 19 |
| ROV3R with wheels | 23 |
| touch sensor bumper | 25 |
| ROV3R with touch sensor bumper | 27 |
| line-following module..... | 28 |
| line-following ROV3R | 28 |
| front IR sensor | 30 |
| ROV3R with front IR sensor | 31 |
| wall-following module..... | 32 |
| wall-following ROV3R | 32 |
| alternative: ROV3R with wall-following and line-following modules | 33 |
| Dexter's cleaning tool..... | 34 |

| | |
|---|-----------|
| ROV3R with cleaning tool..... | 36 |
| alternative #1: ROV3R with cleaning tool and touch sensor bumper..... | 38 |
| alternative #2: wall-following ROV3R with cleaning tool | 39 |
| ROV3R with treads | 40 |
| secret project: grabber module..... | 44 |
| conclusion..... | 44 |
| 3 | |
| programming | 47 |
| the building blocks of any program | 47 |
| sequences..... | 48 |
| choices..... | 48 |
| loops..... | 48 |
| programming with the brick program app..... | 48 |
| your first brick program | 49 |
| <i>a quick guide to the brick program app</i> | 50 |
| the block palette | 53 |
| the action blocks..... | 54 |
| the wait blocks | 56 |
| <i>experiment 3-1</i> | 58 |
| <i>experiment 3-2</i> | 59 |
| the loop block..... | 58 |
| conclusion..... | 59 |
| 4 | |
| advanced programming with the brick program app..... | 61 |
| ROV3R with touch sensor bumper | 61 |
| making ROV3R drive along geometric paths..... | 62 |
| <i>experiment 4-1</i> | 62 |
| making ROV3R follow lines..... | 62 |
| using the brick program to follow lines..... | 63 |
| improving the motion | 63 |
| <i>experiment 4-2</i> | 63 |
| making ROV3R follow walls..... | 64 |
| improving the motion | 64 |
| <i>experiment 4-3</i> | 65 |
| conclusion..... | 65 |
| 5 | |
| EV3 programming | 69 |
| EV3 software setup..... | 69 |
| EV3 software overview..... | 69 |
| the lobby | 69 |
| the programming interface..... | 70 |
| <i>compiling programs</i> | 71 |
| the hardware page..... | 71 |
| the tools menu | 72 |

| | |
|--|----|
| the programming palettes | 73 |
| project properties..... | 75 |
| connecting the EV3 brick to your computer | 75 |
| importing a brick program..... | 76 |
| analyzing the imported brick program | 76 |
| <i>get rid of that block!</i> | 77 |
| editing the imported brick program..... | 77 |
| going for precision..... | 78 |
| <i>digging deeper: computing the degrees parameter to drive precisely.</i> | 78 |
| <i>digging deeper: computing the degrees parameter to steer precisely.</i> | 79 |
| experimenting with action blocks | 79 |
| controlling the program flow | 81 |
| the switch block | 82 |
| <i>experiment 5-1</i> | 82 |
| <i>experiment 5-2</i> | 83 |
| conclusion..... | 83 |

6 experimenting with the EV3 infrared components 85

| | |
|--|----|
| remote IR beacon | 85 |
| using the remote IR beacon as a remote..... | 86 |
| using sensor blocks and data wires..... | 87 |
| <i>untangling data wires</i> | 87 |
| <i>experiment 6-1</i> | 88 |
| EV3 software features for debugging programs..... | 88 |
| displaying data nicely with the text block | 88 |
| understanding data types | 89 |
| data type conversion | 89 |
| <i>digging deeper: decimal numbers</i> | 90 |
| following the remote IR beacon..... | 90 |
| <i>digging deeper: robot localization</i> | 92 |
| using the basic operations of the math block | 92 |
| <i>experiment 6-2</i> | 93 |
| <i>experiment 6-3</i> | 93 |
| conclusion..... | 93 |

7 the math behind the magic! 95

| | |
|---|-----|
| dealing with measurement noise | 95 |
| the math block in advanced mode | 96 |
| the round block | 96 |
| <i>digging deeper: handling errors from math blocks</i> | 97 |
| the compare block | 98 |
| converting numeric values to logic values | 98 |
| embedded compare blocks | 98 |
| the constant block | 98 |
| improving our wall-following program..... | 98 |
| <i>digging deeper: feedback controllers</i> | 100 |

| | |
|--|------------|
| <i>experiment 7-1</i> | 100 |
| <i>experiment 7-2</i> | 100 |
| <i>experiment 7-3</i> | 100 |
| conclusion..... | 100 |
| 8 | |
| LEGO recipes | 103 |
| the angular beams unveiled | 103 |
| <i>digging deeper: angular beams mystery solved!</i> | 104 |
| triangles vs. rectangles..... | 104 |
| extending beams | 107 |
| bracing..... | 108 |
| cross blocks..... | 110 |
| gears revisited..... | 111 |
| getting gears to mesh together well..... | 111 |
| assembling gears..... | 113 |
| gear combinations..... | 114 |
| 90-degree-coupled gears..... | 115 |
| gear trains..... | 118 |
| the worm gear..... | 119 |
| motion transformation..... | 121 |
| building ideas for the motors | 123 |
| medium motor with front output #1..... | 123 |
| medium motor with front output #2..... | 124 |
| medium motor with single lateral output..... | 125 |
| medium motor with double lateral output | 125 |
| medium motor with single geared-down lateral output | 126 |
| medium motor with gearbox..... | 126 |
| medium motor with multiple outputs..... | 127 |
| large motor with horizontal output | 128 |
| large motor gearing options | 128 |
| conclusion..... | 128 |
| 9 | |
| building WATCHGOOZ3 | 131 |
| how does WATCHGOOZ3 walk? | 131 |
| 10 | |
| programming WATCHGOOZ3..... | 177 |
| the brick program for WATCHGOOZ3 | 177 |
| the program..... | 177 |
| how it works..... | 177 |
| running and troubleshooting the robot | 178 |
| importing and editing the program in the EV3 software..... | 178 |
| making a backup..... | 179 |
| modifying the program..... | 179 |
| creating My Blocks with the My Block Builder tool..... | 180 |
| creating My Blocks with inputs and outputs..... | 181 |

| | |
|--|------------|
| automatically adding inputs and outputs to My Blocks..... | 183 |
| additional configuration of a My Block..... | 184 |
| creating an advanced program..... | 184 |
| the ResetBody My Block..... | 184 |
| creating the advanced My Block for walking..... | 185 |
| the final program for WATCHGOOZ3..... | 187 |
| the logic operations block..... | 187 |
| the timer block | 187 |
| <i>experiment 10-1</i> | 187 |
| <i>digging deeper: motor speed regulation</i> | 188 |
| <i>experiment 10-2</i> | 188 |
| conclusion..... | 188 |
| 11 | |
| building the SUP3R CAR | 191 |
| building the R3MOTE | 222 |
| conclusion..... | 227 |
| 12 | |
| programming the SUP3R CAR..... | 231 |
| electronic vs. mechanical differentials..... | 231 |
| <i>digging deeper: computing wheel speeds for an electronic differential</i> | 232 |
| using variables | 232 |
| using arrays | 233 |
| using the variable block with numeric and logic arrays..... | 233 |
| using the array operations block..... | 233 |
| using the switch block with multiple cases | 234 |
| running parallel sequences (multitasking)..... | 234 |
| building the My Blocks | 235 |
| the ResetSteer My Block | 235 |
| the Steer My Block..... | 236 |
| the Drive My Block..... | 236 |
| the ReadRemote2 My Block..... | 237 |
| programming the car to drive around | 239 |
| programming the car for remote control..... | 240 |
| using arrays to clean up the ReadRemote My Block | 240 |
| programming the car to follow the beacon | 242 |
| the Sign My Block..... | 242 |
| the Saturation My Block..... | 242 |
| the ReadBeacon My Block..... | 242 |
| the range block..... | 244 |
| the FollowBeacon program..... | 244 |
| <i>experiment 12-1</i> | 244 |
| adding a siren effect to the SUP3R CAR..... | 245 |
| the loop interrupt block | 246 |
| the stop program block..... | 246 |
| <i>experiment 12-2</i> | 246 |
| conclusion..... | 246 |

| | | |
|--|--------------------------------------|------------|
| 13 | building the SENTIN3L | 249 |
| building the COLOR CUB3..... | 290 | |
| conclusion..... | 292 | |
| 14 | programming the SENTIN3L..... | 295 |
| the file access block..... | 295 | |
| creating and deleting a file and writing data | 295 | |
| reading data from a file..... | 296 | |
| detecting the end of a file | 296 | |
| the random block..... | 296 | |
| building the My Blocks | 296 | |
| the ResetLegs My Block..... | 296 | |
| <i>digging deeper: how “power” relates to speed.</i> | 297 | |
| the WalkFWD My Block | 298 | |
| the Laser My Block | 298 | |
| the Turn My Block | 299 | |
| the PowerDownFX My Block | 299 | |
| the WaitButton My Block | 299 | |
| the SayColor My Block | 300 | |
| the ExeCode My Block..... | 300 | |
| the MakeProgram My Block | 300 | |
| the RunProgram My Block..... | 301 | |
| the MakePrgFile My Block..... | 303 | |
| the ParseFile My Block..... | 303 | |
| the RunPrgFile My Block | 304 | |
| programming the SENTIN3L to patrol | 304 | |
| color-programming the SENTIN3L at runtime..... | 304 | |
| <i>experiment 14-1</i> | 305 | |
| <i>experiment 14-2</i> | 305 | |
| making permanent runtime color programs | 306 | |
| <i>experiment 14-3</i> | 306 | |
| <i>experiment 14-4</i> | 306 | |
| conclusion..... | 306 | |
| 15 | building the T-R3X | 309 |
| conclusion..... | 357 | |
| 16 | programming the T-R3X..... | 363 |
| building the My Blocks for the Wander program..... | 363 | |
| the Reset My Block..... | 363 | |
| the MoveAbsolute and MoveAbsolute2 My Blocks..... | 363 | |
| the Step My Block..... | 364 | |
| the Roar My Block..... | 364 | |
| the Chew My Block..... | 364 | |

| | |
|--|------------|
| the Look My Block | 365 |
| the Right My Block | 365 |
| the Left My Block | 366 |
| the TurnUntil My Block | 366 |
| programming the T-R3X to wander | 367 |
| designing the behavior of the T-R3X | 367 |
| <i>digging deeper: behavior modeling using state machines</i> | 368 |
| implementing a state machine | 369 |
| general structure | 369 |
| starting state | 369 |
| state variable | 370 |
| transitions | 370 |
| sensor events | 370 |
| timer events | 370 |
| timer-filtered events | 371 |
| actions | 371 |
| <i>digging deeper: computing complex logic operations using the math block</i> | 371 |
| <i>digging deeper: De Morgan's laws</i> | 373 |
| making the My Blocks for the final program | 373 |
| the Turn My Block | 373 |
| the ReadBeacon My Block | 373 |
| the INIT My Block | 374 |
| the IDLE My Block | 374 |
| the HUNGRY My Block | 374 |
| the SEEK My Block | 376 |
| the CHASE My Block | 376 |
| <i>ordering state transitions by priority</i> | 377 |
| programming the T-R3X's behavior | 377 |
| <i>experiment 16-1</i> | 379 |
| <i>experiment 16-2</i> | 379 |
| <i>experiment 16-3</i> | 379 |
| <i>experiment 16-4</i> | 379 |
| conclusion | 379 |
| A | |
| the EV3 31313 set bill of materials | 381 |
| <i>looking up pieces on Brickset</i> | 381 |
| B | |
| differences between the education set and retail set | 389 |
| electronic devices | 389 |
| the EV3 software | 389 |
| turning the retail set into the education core set | 389 |
| turning the education core set into the retail set | 394 |
| turning the education expansion set into the retail set | 398 |
| index | 403 |