

Contents

Preface	vii
Printed vs PDF Versions of the Book	ix
Changes Since Groovy	xi
1. Purpose of this Book	1
2. Real and Simulated Robots	3
2.1 Gazebo, Stage, and the ArbotiX Simulator	3
2.2 Introducing the TurtleBot, Maxwell and Pi Robot	4
3. Operating Systems and ROS Versions	5
3.1 Installing Ubuntu Linux	5
3.2 Getting Started with Linux	6
3.3 A Note about Updates and Upgrades	7
4. Reviewing the ROS Basics	9
4.1 Installing ROS	9
4.2 Installing rosinstall	9
4.3 Building ROS Packages with Catkin	10
4.4 Creating a catkin Workspace	10
4.5 Doing a "make clean" with catkin	11
4.6 Rebuilding a Single catkin Package	11
4.7 Mixing catkin and rosbuilt Workspaces	12
4.8 Working through the Official ROS Tutorials	13
4.9 RViz: The ROS Visualization Tool	13
4.10 Using ROS Parameters in your Programs	14
4.11 Using rqt_reconfigure (formerly dynamic_reconfigure) to set ROS Parameters	14
4.12 Networking Between a Robot and a Desktop Computer	16
4.12.1 Time Synchronization	16
4.12.2 ROS Networking using Zeroconf	16
4.12.3 Testing Connectivity	17
4.12.4 Setting the ROS_MASTER_URI and ROS_HOSTNAME Variables	17
4.12.5 Opening New Terminals	18
4.12.6 Running Nodes on both Machines	19
4.12.7 ROS Networking across the Internet	20
4.13 ROS Recap	21
4.14 What is a ROS Application?	21
4.15 Installing Packages with SVN, Git, and Mercurial	22
4.15.1 SVN	23

4.15.2 Git	23
4.15.3 Mercurial	24
4.16 Removing Packages from your Personal catkin Directory	24
4.17 How to Find Third-Party ROS Packages	25
4.17.1 Searching the ROS Wiki	25
4.17.2 Using the roslocate Command	25
4.17.3 Browsing the ROS Software Index	27
4.17.4 Doing a Google Search	27
4.18 Getting Further Help with ROS	27
5. Installing the ros-by-example Code	29
5.1 Installing the Prerequisites	29
5.2 Cloning the Hydro ros-by-example Repository	29
5.2.1 Upgrading from Electric or Fuerte	29
5.2.2 Upgrading from Groovy	30
5.2.3 Cloning the rbx1 repository for Hydro	30
5.3 About the Code Listings in this Book	31
6. Installing the Arbotix Simulator	33
6.1 Installing the Simulator	33
6.2 Testing the Simulator	33
6.3 Running the Simulator with Your Own Robot	35
7. Controlling a Mobile Base	37
7.1 Units and Coordinate Systems	37
7.2 Levels of Motion Control	37
7.2.1 Motors, Wheels, and Encoders	38
7.2.2 Motor Controllers and Drivers	38
7.2.3 The ROS Base Controller	38
7.2.4 Frame-Base Motion using the move_base ROS Package	39
7.2.5 SLAM using the gmapping and amcl ROS Packages	39
7.2.6 Semantic Goals	40
7.2.7 Summary	40
7.3 Twisting and Turning with ROS	41
7.3.1 Example Twist Messages	41
7.3.2 Monitoring Robot Motion using RViz	42
7.4 Calibrating Your Robot's Odometry	44
7.4.1 Linear Calibration	45
7.4.2 Angular Calibration	46
7.5 Sending Twist Messages to a Real Robot	47
7.6 Publishing Twist Messages from a ROS Node	49
7.6.1 Estimating Distance and Rotation Using Time and Speed	49
7.6.2 Timed Out-and-Back in the ArbotiX Simulator	49
7.6.3 The Timed Out-and-Back Script	50
7.6.4 Timed Out and Back using a Real Robot	55
7.7 Are We There Yet? Going the Distance with Odometry	57
7.8 Out and Back Using Odometry	59
7.8.1 Odometry-Based Out and Back in the ArbotiX Simulator	59

7.8.2	Odometry-Based Out and Back Using a Real Robot	60
7.8.3	The Odometry-Based Out-and-Back Script	62
7.8.4	The /odom Topic versus the /odom Frame	67
7.9	Navigating a Square using Odometry	68
7.9.1	Navigating a Square in the ArbotiX Simulator	68
7.9.2	Navigating a Square using a Real Robot	69
7.9.3	The nav_square.py Script	71
7.9.4	The Trouble with Dead Reckoning	71
7.10	Teleoperating your Robot	71
7.10.1	Using the Keyboard	72
7.10.2	Using a Logitech Game Pad	73
7.10.3	Using the ArbotiX Controller GUI	73
7.10.4	TurtleBot Teleoperation Using Interactive Markers	74
7.10.5	Writing your Own Teleop Node	74
8.	Navigation, Path Planning and SLAM	75
8.1	Path Planning and Obstacle Avoidance using move_base	75
8.1.1	Specifying Navigation Goals Using move_base	76
8.1.2	Configuration Parameters for Path Planning	77
8.1.2.1	<i>base_local_planner_params.yaml</i>	78
8.1.2.2	<i>costmap_common_params.yaml</i>	79
8.1.2.3	<i>global_costmap_params.yaml</i>	80
8.1.2.4	<i>local_costmap_params.yaml</i>	80
8.2	Testing move_base in the ArbotiX Simulator	81
8.2.1	Point and Click Navigation in RViz	86
8.2.2	Navigation Display Types for RViz	87
8.2.3	Navigating a Square using move_base	87
8.2.4	Avoiding Simulated Obstacles	94
8.2.5	Setting Manual Goals with Obstacles Present	97
8.3	Running move_base on a Real Robot	97
8.3.1	Testing move_base without Obstacles	97
8.3.2	Avoiding Obstacles using a Depth Camera as a Fake Laser	99
8.4	Map Building using the gmapping Package	101
8.4.1	Laser Scanner or Depth Camera?	102
8.4.2	Collecting and Recording Scan Data	104
8.4.3	Creating the Map	106
8.4.4	Creating a Map from Bag Data	106
8.4.5	Can I Extend or Modify an Existing Map?	108
8.5	Navigation and Localization using a Map and amcl	108
8.5.1	Testing amcl with Fake Localization	108
8.5.2	Using amcl with a Real Robot	110
8.5.3	Fully Autonomous Navigation	113
8.5.4	Running the Navigation Test in Simulation	113
8.5.5	Understanding the Navigation Test Script	115
8.5.6	Running the Navigation Test on a Real Robot	120
8.5.7	What's Next?	122
9.	Speech Recognition and Synthesis	123
9.1	Installing PocketSphinx for Speech Recognition	123

9.2 Testing the PocketSphinx Recognizer	123
9.3 Creating a Vocabulary	125
9.4 A Voice-Control Navigation Script	127
9.4.1 Testing Voice-Control in the ArbotiX Simulator	132
9.4.2 Using Voice-Control with a Real Robot	133
9.5 Installing and Testing Festival Text-to-Speech	134
9.5.1 Using Text-to-Speech within a ROS Node	136
9.5.2 Testing the talkback.py script	138
10. Robot Vision	139
10.1 OpenCV, OpenNI and PCL	139
10.2 A Note about Camera Resolutions	140
10.3 Installing and Testing the ROS Camera Drivers	140
10.3.1 Installing the OpenNI Drivers	140
10.3.2 Installing Webcam Drivers	140
10.3.3 Testing your Kinect or Xtion Camera	141
10.3.4 Testing your USB Webcam	142
10.4 Installing OpenCV on Ubuntu Linux	143
10.5 ROS to OpenCV: The cv_bridge Package	144
10.6 The ros2opencv2.py Utility	149
10.7 Processing Recorded Video	151
10.8 OpenCV: The Open Source Computer Vision Library	152
10.8.1 Face Detection	152
10.8.2 Keypoint Detection using GoodFeaturesToTrack	158
10.8.3 Tracking Keypoints using Optical Flow	164
10.8.4 Building a Better Face Tracker	170
10.8.5 Dynamically Adding and Dropping Keypoints	173
10.8.6 Color Blob Tracking (CamShift)	175
10.9 OpenNI and Skeleton Tracking	181
10.9.1 Checking your OpenNI installation for Hydro	182
10.9.2 Viewing Skeletons in RViz	183
10.9.3 Accessing Skeleton Frames in your Programs	183
10.10 PCL Nodelets and 3D Point Clouds	191
10.10.1 The PassThrough Filter	191
10.10.2 Combining More than One PassThrough Filter	193
10.10.3 The VoxelGrid Filter	194
11. Combining Vision and Base Control	197
11.1 A Note about Camera Coordinate Axes	197
11.2 Object Tracker	197
11.2.1 Testing the Object Tracker with rqt_plot	197
11.2.2 Testing the Object Tracker with a Simulated Robot	198
11.2.3 Understanding the Object Tracker Code	199
11.2.4 Object Tracking on a Real Robot	205
11.3 Object Follower	206
11.3.1 Adding Depth to the Object Tracker	206
11.3.2 Testing the Object Follower with a Simulated Robot	210
11.3.3 Object Following on a Real Robot	211

11.4 Person Follower	212
11.4.1 Testing the Follower Application in Simulation	213
11.4.2 Understanding the Follower Script	213
11.4.3 Running the Follower Application on a TurtleBot	217
11.4.4 Running the Follower Node on a Filtered Point Cloud	218
12. Dynamixel Servos and ROS	219
12.1 A TurtleBot with a Pan-and-Tilt Head	220
12.2 Choosing a Dynamixel Hardware Controller	220
12.3 A Note Regarding Dynamixel Hardware	221
12.4 Choosing a ROS Dynamixel Package	221
12.5 Understanding the ROS JointState Message Type	221
12.6 Controlling Joint Position, Speed and Torque	222
12.6.1 Setting Servo Position	223
12.6.2 Setting Servo Speed	224
12.6.3 Controlling Servo Torque	224
12.7 Checking the USB2Dynamixel Connection	225
12.8 Setting the Servo Hardware IDs	226
12.9 Configuring and Launching dynamixel_controllers	227
12.9.1 The dynamixel_controllers Configuration File	227
12.9.2 The dynamixel_controllers Launch File	228
12.10 Testing the Servos	230
12.10.1 Starting the Controllers	230
12.10.2 Monitoring the Robot in RViz	231
12.10.3 Listing the Controller Topics and Monitoring Joint States	231
12.10.4 Listing the Controller Services	233
12.10.5 Setting Servo Position, Speed and Torque	234
12.10.6 Using the relax_all_servos.py Script	235
12.11 Tracking a Visual Target	236
12.11.1 Tracking a Face	236
12.11.2 The Head Tracker Script	237
12.11.3 Tracking Colored Objects	244
12.11.4 Tracking Manually Selected Targets	245
12.12 A Complete Head Tracking ROS Application	246
13. Where to Go Next?	249