

Main Chapter Headings

Preface.....	v
Printed vs PDF Versions of the Book.....	vii
Changes Since Hydro.....	ix
1. Purpose of this Book.....	1
2. Real and Simulated Robots.....	3
3. Operating Systems and ROS Versions.....	5
4. Reviewing the ROS Basics.....	7
5. Installing the ros-by-example Code.....	27
6. Installing the Arbotix Simulator.....	31
7. Controlling a Mobile Base.....	35
8. Navigation, Path Planning and SLAM.....	75
9. Speech Recognition and Synthesis.....	123
10. Robot Vision.....	139
11. Combining Vision and Base Control.....	201
12. Dynamixel Servos and ROS.....	227
13. Where to Go Next?.....	257
Links Referenced in the Text.....	261

Table of Contents

Preface.....	v
Printed vs PDF Versions of the Book.....	vii
Changes Since Hydro.....	ix
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.....	6
4. Reviewing the ROS Basics.....	7
4.1 Installing ROS.....	7
4.2 Installing rosinstall.....	7
4.3 Building ROS Packages with Catkin.....	8
4.4 Creating a catkin Workspace.....	8
4.5 Doing a "make clean" with catkin.....	9
4.6 Rebuilding a Single catkin Package.....	9
4.7 Mixing catkin and rosbuilt Workspaces.....	10
4.8 Working through the Official ROS Tutorials.....	11
4.9 RViz: The ROS Visualization Tool.....	11
4.10 Using ROS Parameters in your Programs.....	12
4.11 Using rqt_reconfigure (formerly dynamic_reconfigure) to set ROS Parameters	12
4.12 Networking Between a Robot and a Desktop Computer.....	14
4.12.1 Time Synchronization.....	14
4.12.2 ROS Networking using Zeroconf.....	14
4.12.3 Testing Connectivity.....	15
4.12.4 Setting the ROS_MASTER_URI and ROS_HOSTNAME Variables.....	15
4.12.5 Opening New Terminals.....	16
4.12.6 Running Nodes on both Machines.....	17
4.12.7 ROS Networking across the Internet.....	18
4.13 ROS Recap.....	19
4.14 What is a ROS Application?.....	19
4.15 Installing Packages with SVN, Git, and Mercurial.....	20
4.15.1 SVN.....	21
4.15.2 Git.....	21
4.15.3 Mercurial.....	22
4.16 Removing Packages from your Personal catkin Directory.....	22
4.17 How to Find Third-Party ROS Packages.....	23

4.17.1 Searching the ROS Wiki.....	23
4.17.2 Using the roslocate Command.....	23
4.17.3 Browsing the ROS Software Index.....	24
4.17.4 Doing a Google Search.....	24
4.18 Getting Further Help with ROS.....	24
5. Installing the ros-by-example Code.....	27
5.1 Installing the Prerequisites.....	27
5.2 Cloning the Indigo ros-by-example Repository.....	27
5.2.1 Upgrading from Electric or Fuerte.....	28
5.2.2 Upgrading from Groovy.....	28
5.2.3 Upgrading from Hydro.....	28
5.2.4 Cloning the rbx1 repository for Indigo for the first time.....	28
5.3 About the Code Listings in this Book.....	30
6. Installing the Arbotix Simulator.....	31
6.1 Installing the Simulator.....	31
6.2 Testing the Simulator.....	31
6.3 Running the Simulator with Your Own Robot.....	32
7. Controlling a Mobile Base.....	35
7.1 Units and Coordinate Systems.....	35
7.2 Levels of Motion Control.....	35
7.2.1 Motors, Wheels, and Encoders.....	36
7.2.2 Motor Controllers and Drivers.....	36
7.2.3 The ROS Base Controller.....	36
7.2.4 Frame-Base Motion using the move_base ROS Package.....	37
7.2.5 SLAM using the gmapping and amcl ROS Packages.....	37
7.2.6 Semantic Goals.....	38
7.2.7 Summary.....	38
7.3 Twisting and Turning with ROS.....	39
7.3.1 Example Twist Messages.....	39
7.3.2 Monitoring Robot Motion using RViz.....	40
7.4 Calibrating Your Robot's Odometry.....	42
7.4.1 Linear Calibration.....	43
7.4.2 Angular Calibration.....	44
7.5 Sending Twist Messages to a Real Robot.....	45
7.6 Publishing Twist Messages from a ROS Node.....	46
7.6.1 Estimating Distance and Rotation Using Time and Speed.....	47
7.6.2 Timed Out-and-Back in the ArbotiX Simulator.....	47
7.6.3 The Timed Out-and-Back Script.....	48
7.6.4 Timed Out and Back using a Real Robot.....	53
7.7 Are We There Yet? Going the Distance with Odometry.....	55
7.8 Out and Back Using Odometry.....	57
7.8.1 Odometry-Based Out and Back in the ArbotiX Simulator.....	58
7.8.2 Odometry-Based Out and Back Using a Real Robot.....	59
7.8.3 The Odometry-Based Out-and-Back Script.....	60
7.8.4 The /odom Topic versus the /odom Frame.....	66

7.9 Navigating a Square using Odometry.....	66
7.9.1 Navigating a Square in the ArbotiX Simulator.....	67
7.9.2 Navigating a Square using a Real Robot.....	68
7.9.3 The nav_square.py Script.....	69
7.9.4 The Trouble with Dead Reckoning.....	69
7.10 Teleoperating your Robot.....	70
7.10.1 Using the Keyboard.....	70
7.10.2 Using a Logitech Game Pad.....	71
7.10.3 Using the ArbotiX Controller GUI.....	72
7.10.4 TurtleBot Teleoperation Using Interactive Markers.....	73
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 base_local_planner_params.yaml.....	78
8.1.2.2 costmap_common_params.yaml.....	79
8.1.2.3 global_costmap_params.yaml.....	80
8.1.2.4 local_costmap_params.yaml.....	80
8.2 Testing move_base in the ArbotiX Simulator.....	82
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?.....	101
8.4.2 Collecting and Recording Scan Data.....	103
8.4.3 Creating the Map.....	105
8.4.4 Creating a Map from Bag Data.....	106
8.4.5 Can I Extend or Modify an Existing Map?.....	107
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.....	121
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 ROS OpenNI and OpenKinect (freenect) Drivers.....	140
10.3.2 Installing a Webcam Driver.....	140
10.3.3 Testing your Kinect or Xtion Camera.....	141
10.3.4 Turning on Depth Registration.....	142
10.3.5 Testing your USB Webcam.....	143
10.4 Installing OpenCV on Ubuntu Linux.....	143
10.5 ROS to OpenCV: The cv_bridge Package.....	144
10.6 The ros2opencv2.py Utility.....	150
10.7 Reducing Video Processing Load.....	152
10.7.1 Data skipping.....	152
10.7.2 Topic Throttling.....	154
10.8 Processing Recorded Video.....	155
10.9 OpenCV: The Open Source Computer Vision Library.....	155
10.9.1 Face Detection.....	156
10.9.2 Keypoint Detection using GoodFeaturesToTrack.....	162
10.9.3 Tracking Keypoints using Optical Flow.....	168
10.9.4 Building a Better Face Tracker.....	174
10.9.5 Dynamically Adding and Dropping Keypoints.....	177
10.9.6 Color Blob Tracking (CamShift).....	179
10.10 OpenNI and Skeleton Tracking.....	186
10.10.1 Installing NITE and openni_tracker for ROS Indigo.....	186
10.10.2 Viewing Skeletons in RViz.....	187
10.10.3 Accessing Skeleton Frames in your Programs.....	188
10.11 PCL Nodelets and 3D Point Clouds.....	196
10.11.1 The PassThrough Filter.....	196
10.11.2 Combining More than One PassThrough Filter.....	198
10.11.3 The VoxelGrid Filter.....	199
11. Combining Vision and Base Control.....	201
11.1 A Note about Camera Coordinate Axes.....	201
11.2 Object Tracker.....	201
11.2.1 Testing the Object Tracker with rqt_plot.....	201
11.2.2 Testing the Object Tracker with a Simulated Robot.....	203
11.2.3 Understanding the Object Tracker Code.....	204
11.2.4 Object Tracking on a Real Robot.....	210
11.3 Object Follower.....	211
11.3.1 Adding Depth to the Object Tracker.....	211
11.3.2 Testing the Object Follower with a Simulated Robot.....	215
11.3.3 Object Following on a Real Robot.....	216
11.4 Person Follower.....	217

11.4.1 Testing the Follower Application in Simulation.....	218
11.4.2 Understanding the Follower Script.....	219
11.4.3 Running the Follower Application on a TurtleBot.....	223
11.4.4 Running the Follower Node on a Filtered Point Cloud.....	224
12. Dynamixel Servos and ROS.....	227
12.1 A TurtleBot with a Pan-and-Tilt Head.....	228
12.2 Choosing a Dynamixel Hardware Controller.....	228
12.3 A Note Regarding Dynamixel Hardware.....	229
12.4 Choosing a ROS Dynamixel Package.....	229
12.5 Understanding the ROS JointState Message Type.....	229
12.6 Controlling Joint Position, Speed and Torque.....	230
12.6.1 Setting Servo Position.....	231
12.6.2 Setting Servo Speed.....	232
12.6.3 Controlling Servo Torque.....	232
12.7 Checking the USB2Dynamixel Connection.....	233
12.8 Setting the Servo Hardware IDs.....	233
12.9 Configuring and Launching dynamixel_controllers.....	235
12.9.1 The dynamixel_controllers Configuration File.....	235
12.9.2 The dynamixel_controllers Launch File.....	236
12.10 Testing the Servos.....	238
12.10.1 Starting the Controllers.....	238
12.10.2 Monitoring the Robot in RViz.....	239
12.10.3 Listing the Controller Topics and Monitoring Joint States.....	239
12.10.4 Listing the Controller Services.....	241
12.10.5 Setting Servo Position, Speed and Torque.....	241
12.10.6 Using the relax_all_servos.py Script.....	243
12.11 Tracking a Visual Target.....	243
12.11.1 Tracking a Face.....	243
12.11.2 The Head Tracker Script.....	245
12.11.3 Tracking Colored Objects.....	252
12.11.4 Tracking Manually Selected Targets.....	253
12.12 A Complete Head Tracking ROS Application.....	254
13. Where to Go Next?.....	257
Links Referenced in the Text.....	261