

# A Gentle Introduction to ROS

Back matter

Jason M. O'Kane

Jason M. O’Kane  
University of South Carolina  
Department of Computer Science and Engineering  
315 Main Street  
Columbia, SC 29208

<http://www.cse.sc.edu/~jokane>

©2014, Jason Matthew O’Kane. All rights reserved.

This is version 2.1.3 (5776342), generated on April 20, 2016.

Typeset by the author using  $\text{\LaTeX}$  and `memoir.cls`.

ISBN 978-14-92143-23-9

---

# Index

- , 28
- /, 23, 50, 78, 79, 93, 108, 114, *see also* names, global
- ::, 49
- :=, 94, 113
- <<, 63
- [], 31
- &, 58
- ▶▶, 7, 8, 12, 13, 15, 17, 20–23, 31, 32, 34, 39, 41–43, 50, 52, 57, 58, 64, 68, 70, 73, 74, 76, 81, 84, 85, 87, 90, 91, 93, 102, 103, 106, 107, 109, 111, 114, 122, 126, 129
- ⌋, 113
- ☐, 1, 3–5, 7–9, 11–15, 17, 19, 21–24, 27, 30–32, 37, 39, 40, 42, 44, 47, 49–51, 53, 55, 57, 59, 61, 64, 68–70, 72, 77, 83, 87, 88, 90, 93, 94, 97, 99, 102, 105, 109, 110, 113, 114, 118, 123, 126, 131, 133, 139, 142, 143
- ^[[0m, 68
- ⚡, 7, 8, 12–20, 24–26, 28, 32, 33, 40, 41, 45, 47, 50, 53, 54, 58–60, 64, 69, 73, 74, 81, 84, 87, 89, 97, 99, 103, 107, 108, 121–123, 125, 126, 134, 135, 137, 139
- ~, 80, 113, 114, 129
- account configuration, 14–15
- add\_executable, 45
- advertise, 49, 50, 129
- agitr, 41, 42, 83
- angular, 30, 95
- anon, 88
- anon.cpp, 82
- answers.ros.org, 7
- apt, 12
- apt-get, 13, 18
  - install, 13
  - update, 12
- apt-key, 12

- arg, 99–103
- args, 139
- arrays, 31
- audience, 5
  
- bag files, 133–135
  - API, 139
  - compression, 134
  - example, 135–138
  - inspecting, 134
  - recording, 133, 135
  - replaying, 134, 136
- bash, 5, 15, 32, 107
- .bashrc, 15
- bool, 30, 110
- box turtle, 8
- build, 45
- build systems, 9
- build\_depend, 44, 127
- built-in data type, 30
  
- C Turtle, 8
- C++, 4, 5, 9, 31, 41, 44, 47, 49, 51, 58, 62–67, 73, 74, 80, 81, 96, 110–112, 121–123, 125, 139
- call, 125–127
- callback functions, 55, 127, 130, 142
  - allowing, 59, 130
  - timers, 131
- catkin, 9, 17, 18, 40, 41, 44, 47
- catkin\_create\_pkg, 40, 41, 45
- catkin\_make, 45–47, 54, 127
- /clear, 109, 110
- CMake, 40, 45
- CMAKE\_PREFIX\_PATH, 18
- CMakeLists.txt, 40, 41, 44–46, 54, 127
  - editing, 45
- cmd\_vel, 26, 78, 79, 122
  
- coding style, 142
- color\_sensor, 122
- communication
  - many-to-many, 36
  - one-to-one, 117
- complexity via composition, 2, 36, 80
- coordinate frames, 142
- count.cpp, 63, 64, 67, 70
- Ctrl-C, 20, 24, 52, 85, 134
  
- data types, 29, *see also* messages, types,  
*see also* services, types
- deb, 14, 17
- DEBUG, 61, 62, 64, 68, 73, 74, 76
- Debug, 76
- default, 100, 101
- description, 41
- devel, 45
- /diagnostics, 71
- /diagnostics\_agg, 71
- diamondback, 8
- double, 51, 63, 66, 110
- doublesim.launch, 91, 92, 97
- draw\_square, 135–138
- dynamic\_reconfigure, 109
  
- electric, 8
- eog, 19
- ERROR, 61, 62, 68, 74, 88
- Error, 76
- example.launch, 83, 84, 90
- executables, adding to package, 45
- export, 14, 80
  
- fast\_yellow.launch, 115
- FATAL, 61, 62, 68, 74, 88
- Fatal, 76
- \${file}, 69
- file, 97

- find, 97, 114
- find\_package, 44, 45, 54, 127
- float64, 51
- frame\_id, 143
- fuerte, 8, 18
- `{function}`, 69
- function pointers, 58, 130
  
- Gazebo, 143
- gazebo/ModelState, 34
- gdb, 90
- geometry\_msgs, 8, 54
  - ::Twist, 49, 51
- geometry\_msgs/Pose, 34
- geometry\_msgs/Twist, 9, 30, 32, 49, 51
- geometry\_msgs/Twist.h, 54
- geometry\_msgs/Vector3, 30
- get\_loggers, 119
- graph resource names, *see* names
- graph resources, 77
- groovy, 8, 9, 18, 19
- group, 100–103
  
- hello.cpp, 41–47, 49, 54
  - compiling, 44–47
  - executing, 47
- hydro, 8
  
- IDE, 4
- if, 101, 103
- `#include`, 49, 56, 123
- include, 93, 97, 98, 100–102, 114
- indigo, 8, 106
- INFO, 61, 62, 64, 65, 68, 73, 74, 88
- Info, 76
- init, 42
- int, 63, 110
- int8, 30
  
- jade, 8
  
- launch, 86, 94
- launch files, 83–104
  - arguments, 99–102
    - accessing, 101
    - declaring, 100
    - includes, 101
    - values, 100
  - bags, 139
  - creating, 86–90
  - executing, 83–85
  - groups, 102–103, 113
  - includes, 97–99
  - nodes, 87, 113
    - directing output, 88
    - name, 87
    - output, 69, 103
    - pkg, 87
    - requiring, 89
    - respawning, 89
    - separate window, 90
    - type, 87
  - remappings, 93–95
  - root element, 86
  - rosparam, 114
  - syntax, 86–90
  - terminating, 85
  - verbosity, 85
- launch-prefix, 90
- `{line}`, 69
- linear, 9, 30, 95
- log files, 72
  - finding, 72
  - roslaunch, 88
  - purging, 72
- log messages, 61–76
  - enabling and disabling, 73–76

- from C++, 75
- from command line, 74
- from GUI, 75
- example, 62
- formatting, 68
- generating, 62–67
  - one time, 65
  - simple, 62
  - throttled, 65
- viewing, 67–73
  - in log files, 72–73
  - rosout, 69–71
  - on the console, 68–69
- log4cxx, 64, 74, 75
- logger levels, 73–76, *see also* severity levels
  
- maintainer, 41
- manifest, 40
- master, *see* roscore
- max\_vel, 111, 114, 115
- \${message}, 69
- messages, 24
  - objects, 51
  - publishing, 47–54
  - queues, 50
  - subscribing, 55–60
  - types, 29, 33, 49
    - arrays, 31, 51
    - constants, 31
    - creating, 142
    - fields, 30
    - nesting, 30
- metapackage, 19
- ModelState, 34
- multiple computers, 2, 141
  
- \_\_name, 23, 34, 42
  
- name, 92
- names, 77–82
  - anonymous, 81–82, 87, 136
  - base, 78
  - collisions, 34, 80, 119, 122
  - global, 77–78
  - private, 80–81, 113
  - relative, 50, 78–80
    - purpose, 80
    - resolving, 79
  - remappings, 93–95
- namespaces, 23, 78
  - global, 23, 78
  - launching in, 91–93
  - setting default, 79, *see also* names, relative
  
- nice, 90
- \${node}, 69
- node, 86, 87, 89–92, 94, 102, 103, 113, 114, 139
- NodeHandle, 43, 123, 129, 130
- nodelets, 50
- nodes, 20–24
  - dead, 24
  - inspecting, 23
  - killing, 23
  - listing, 22, 23
  - names, 23, 34, 42, 52, 87
  - services, 120
  - starting, 21
- \_\_ns, 80
- ns, 79, 91, 93, 98, 102, 103
  
- once.cpp, 66
- /opt/ros/indigo, 18
- ostream, 63
- out-of-source compilation, 18

- package authentication key, 12
- package.xml, 17, 40–42, 44, 54, 127
  - editing, 41
- packages, 17–20
  - creating, 40
  - dependencies, 34, 44, 54, 127
  - directories, 17, 86
  - finding, 18
  - listing, 17
  - manifest, *see* package.xml
- param, 87, 113, 114
- parameters, 105–115
  - files, 107, 114
  - in C++, 110–113
  - in launch files, 113–115
    - setting, 113
  - on the command line, 105–108
    - listing, 105
    - querying, 106
    - setting, 107
  - private names, 113
  - server, 105, 106
- play, 139
- polling, 67
- pose, 78, 122
- poses, 55
- printf, 64, 65
- private, 81
- publish, 50, 51
- publishing, *see* messages
- publishing loops, 52–53
- pubvel.cpp, 47–49, 51–55, 60, 111, 112, 135
  - compiling, 54
  - executing, 54
- pubvel\_with\_max.cpp, 112
- pubvel\_toggle.cpp, 128, 130, 131
- pubvel\_with\_max.cpp, 113, 114
- pushing down, 91
- Qt, 24
- record, 139
- redirection, 68
- remap, 87, 93–95, 99
- repository, 11
- Request, 125, 127, 129
- required, 89, 90
- respawn, 89, 90
- Response, 125, 126, 129
- reverse.launch, 98
- reverse\_cmd\_vel, 96, 97
- reversed.launch, 99
- Robot Operating System (ROS), **1–143**
- ROS
  - distributions, 8
  - documentation, 5, 7–9
  - installing, 11–14
  - limitations, 4
  - motivation, 1–4
  - pronunciation, 1
  - uniqueness, 3
  - versions, *see also* indigo, *see* ROS, distributions
- ros
  - ::NodeHandle, 42, 49, 123, 129
    - ::advertiseService, 129
  - ::Publisher, 49–51, 57, 77, 91, 125
  - ::Rate, 53, 131, 142
  - ::ServiceClient, 123, 125, 126
  - ::ServiceServer, 127, 130
  - ::Subscriber, 57–59, 91, 127, 130
  - ::Timer, 142
  - ::console
    - ::notifyLoggerLevelsChanged, 76

- `::init`, 42, 45, 52, 77, 80, 81, 87, 113, 123
- `::init_options`
  - `::AnonymousName`, 81
- `::ok`, 52
- `::param`
  - `::get`, 99, 110, 111
  - `::getCached`, 110
  - `::set`, 110, 113
- `::shutdown`, 52
- `::spin`, 57, 59, 130, 131
- `::spinOnce`, 57, 59, 130, 131
- `ros-indigo-desktop`, 13
- `ros-indigo-ros-base`, 13
- `ros-indigo-turtlesim`, 11
- `ros-users`, 8
- `ros.key`, 12
- `ros/ros.h`, 42, 45
- `ROS_DEBUG_STREAM`, 73
- `ROS_DISTRO`, 15
- `ROS_ERROR_STREAM`, 126
- `ROS_INFO_STREAM`, 43, 47, 52, 55, 56, 60, 61, 73
- `ROS_PACKAGE_PATH`, 15
- `ROS_DEBUG`, 64
- `ROS_DEBUG_STREAM`, 62, 73
  - `..._ONCE`, 65
  - `..._THROTTLE`, 65
- `ROS_ERROR`, 64
- `ROS_ERROR_STREAM`, 62
  - `..._ONCE`, 65
  - `..._THROTTLE`, 65
- `ROS_FATAL`, 64
- `ROS_FATAL_STREAM`, 62
  - `..._ONCE`, 65
  - `..._THROTTLE`, 65
- `ROS_INFO`, 64
- `ROS_INFO_STREAM`, 62
  - `..._ONCE`, 65
  - `..._THROTTLE`, 65
- `ROS_WARN`, 64
- `ROS_WARN_STREAM`, 62
  - `..._ONCE`, 65
  - `..._THROTTLE`, 65
- `roscpp`, 3, 33, 131, 133–140
  - `info`, 134
  - `play`, 134, 136, 137
  - `record`, 133, 135
    - `-a`, 134
- `rosclean`
  - `check`, 72
  - `purge`, 73
- `ROSCONSOLE_FORMAT`, 68
- `roscore`, 16, 20–22, 34, 47, 72, 83, 84, 106, 108, 136
- `roscpp`, 43, 44, 46, 54
- `roscd`, 15, 18, 19
- `rosclean`
  - `check`, 72
  - `purge`, 73
- `ROSCONSOLE_FORMAT`, 68
- `roscore`, 16, 20–22, 34, 47, 72, 83, 84, 106, 108, 136
- `roscpp`, 43, 44, 46, 54
- `rosdep`, 13, 14, 37
  - `init`, 13, 14
  - `update`, 14
- `/rosdistro`, 106
- `rosgraph_msgs/Log`, 69, 70
- `roinstall`, 14
- `roslaunch`, 21, 69, 72, 81–86, 88–90, 92, 97–99, 101, 106, 113, 139
  - `--screen`, 69, 88
  - `-v`, 85
- `rosls`, 15, 18, 19
- `rosmmsg`, 121
  - `show`, 30, 51, 56
- `rosclean`
  - `cleanup`, 24
  - `info`, 23, 55, 77, 119
  - `kill`, 23, 52



- list, 22, 23
- /rosout, 120
- rosout, 22, 25, 68, 69, 71, 72, 120
- rosout.log, 72
- rosout\_agg, 70, 71
- rospack, 18, 47
  - find, 18
  - list, 17
- rosparam, 99, 107
  - dump, 107, 114
  - get, 72, 106, 109
  - list, 105, 108
  - load, 108, 114, 115
  - set, 107, 111, 113
- rostrun, 21–23, 34, 42, 47, 54, 84, 87, 88,  
90, 93, 95, 139
- rosservice, 74, 75, 121
  - call, 74, 109, 122, 130, 131
  - info, 120
  - list, 118, 119
  - node, 120
- rossrv, 121
  - show, 121, 122, 125
- rostopic, 31, 121
  - bw, 28
  - echo, 28, 33, 69, 77
  - hz, 28, 53
  - info, 28, 56
  - list, 27, 50, 55
  - pub, 31, 33
    - 1 (dash one), 33
    - l (dash ell), 33
- roswtf, 37
- rqt\_console, 69, 70, 73
- rqt\_graph, 24–27, 35, 50, 55, 135
- rqt\_logger\_level, 75
- run\_depend, 44, 127
- run\_id, 72, 78, 88
- rviz, 142
- sensor\_msgs/NavSatFix, 31
- ServiceClient, 125
- serviceClient, 123
- services, 36, 117–132
  - calling, 125
  - clients, writing, 123–127
  - from the command line, 118–122
  - listing, 118, 119
  - request and response objects, 123, 125
  - servers, 129
    - in C++, 127–131
  - types, 118
    - creating, 142
    - finding, 120
    - inspecting, 121
- set\_bg\_color.cpp, 111
- set\_logger\_level, 74, 75, 78, 119
- set\_pen, 122
- setup.bash, 14, 15, 18, 46, 47
- \${severity}, 69
- severity levels, 61–62
- simulation, 3, 143
- sleep, 53, 131
- software reuse, 2
- /spawn, 119, 120
- spawn\_turtle.cpp, 124
- src, 40, 41
- stack, 19
- static, 65, 67
- std
  - ::boolalpha, 64
  - ::cout, 22, 63
  - ::endl, 65
  - ::fixed, 64
  - ::setprecision, 64
  - ::string, 110

- `::stringstream`, 64
- `std_msgs/Header`, 31
- `std_srvs/Empty`, 121, 129
- `stdbuf`, 68
- `string`, 30
- `subpose.cpp`, 56, 60, 84, 88
- `subscribe`, 58
- subscribing, *see* messages
- `sudo`, 12, 14
  
- Tab, 33
- tab completion, 18, 32, 33
- `target_link_libraries`, 45
- `teleop_turtle`, 23, 25, 26, 28, 78, 95
- teleoperation, 21
- `teleport_absolute`, 122
- template parameter, 49
- testing, 3
- `tf`, 142, 143
- `throttle.cpp`, 67
- `${time}`, 69
- `toggle_forward`, 127, 130
- topics, 27–34
- transformations, 143
- `triplesim.launch`, 100
- `turtle1`, 27, 78, 79, 122
  - `/cmd_vel`, 25, 26, 35, 36, 79, 91, 95, 135, 136
  - `/cmd_vel_reversed`, 95
  - `/color_sensor`, 91
  - `/pose`, 55, 91, 94, 135, 137, 138
- `turtle_teleop_key`, 16, 17, 21, 36, 89, 90, 95
- `/turtlesim`, 25
- `turtlesim`, 8, 11, 13, 15–17, 19–21, 23–27, 34–36, 47, 48, 54–56, 60, 62, 78, 83, 84, 89, 91–99, 108–111, 114, 118–120, 122, 127, 136–138, 141, 142
  - `::Pose`, 56
  - `::Spawn`, 123
  - background color
    - reading, 109
    - setting, 109
  - `cmd_vel`, 77
  - `draw_square`, 135
  - installing, 13
  - multiple instances, 34–36
  - parameters, 108–110
  - pose, 77
  - reset, 121, 135, 138
  - reversing directions, 95
  - starting, 16
  - `teleport_absolute`, 122
  - `teleport_relative`, 122
  - `turtle_teleop_key`, 90
- `turtlesim/Color`, 29, 30, 33
- `turtlesim/Pose`, 34, 60
- `turtlesim/Spawn`, 120
- `turtlesim/Velocity`, 9
- `turtlesim_node`, 17, 21, 22, 26, 36, 55, 60, 62, 89, 91, 95, 108, 109, 121, 130, 131, 137
- tutorials, 5, 7
  
- Ubuntu, 5, 11
- universally-unique identifier (UUID), 72
- unless, 103
- usleep, 53
  
- `valgrind`, 90
- value, 100–102
- `void`, 121
  
- WARN, 61, 62, 68, 74
- Warn, 76

- workspaces, 39–41
  - building, 45
  - creating, 39
  - directories, 39

- X, 36

- XML, 83

- xterm, 90

- YAML, 32



---

# Acknowledgments

The author is thankful to the friends, colleagues, and students that have provided feedback and advice about this project.

Students, too numerous to name, from the author's csce574 courses at the University of South Carolina provided priceless feedback on early versions of this book. Michael Reynolds, Laura Boccanfuso, G. vd. Hoorn, Nik Elson, and Mateusz Przybyla helped the author to correct many mistakes in the text. The author is, of course, to blame for any remaining errors.

The author is also grateful to the University of South Carolina for providing a supportive and encouraging environment, and to the U. S. National Science Foundation for a grant that helped to support the author's time for this project. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation.