Introduction to Cognitive Robotics

Module 2: The Robot Operating System (ROS)

Lecture 4: Writing ROS software in C++: Services

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Writing ROS Software

- Creating a ROS workspace and a ROS package
- Writing ROS programs
  1. Example program: Hello World!
  2. Example program to publish messages

     Send velocity messages on `/turtle1/cmd_vel`

Writing ROS Software

- Writing ROS programs

3. Example program to subscribe to messages

   Receive pose messages on `/turtle1/pose`

4. Example program to use services

   ```
   /reset
   /clear
   /turtle1/set_pen
   /turtle1/teleport_absolute
   ```

Example Client Program to Use Services

`/clear`, `/turtle1/set_pen`, `/turtle1/teleport_absolute`

2.1.3 Services

`clear` (std_srvs/Empty)

Clears the turtlesim background and sets the color to the value of the background parameters.

`reset` (std_srvs/Empty)

Resets the turtlesim to the start configuration and sets the background color to the value of the background.

`kill` (turtlesim/Kill)

Kills a turtle by name.

`spawn` (turtlesim/Spawn)

Spawns a turtle at (x, y, theta) and returns the name of the turtle. Also will take name for argument but will fail if a duplicate name.

`turtleX/set_pen` (turtlesim/SetPen)

Sets the pen's color (r g b), width (width), and turns the pen on and off (off).

`turtleX/teleport_absolute` (turtlesim/TeleportAbsolute)

Teleports the turtleX to (x, y, theta).

`turtleX/teleport_relative` (turtlesim/TeleportRelative)

Teleports the turtleX a linear and angular distance from the turtles current position.

http://wiki.ros.org/turtlesim

Example Client Program to Use Services

`/clear, /turtle1/set_pen, /turtle1/teleport_absolute`

Make sure you are in the agitr sub-directory

~/workspace/ros/src$ cd ~/workspace/ros/src/agitr

Example Client Program to Use Services

/clear, /turtle1/set_pen, /turtle1/teleport_absolute

Edit CMakeLists.txt

Add the following lines at the end of the file

```
add_executable(${PROJECT_NAME}_useservices src/useservices.cpp)
set_target_properties(${PROJECT_NAME}_useservices PROPERTIES OUTPUT_NAME useservices  PREFIX "")
target_link_libraries(${PROJECT_NAME}_useservices ${catkin_LIBRARIES})
```

This avoids name pollution and allows different packages to have ROS nodes with the same name

But the executable is still just this so that you can execute it with rosrun package_name node, i.e. rosrun agitr useservices

Example Client Program to Use Services

`/clear, /turtle1/set_pen, /turtle1/teleport_absolute`

Move to the agitr/src sub-directory

```
~/workspace/ros/src/agitr$ cd src
~/workspace/ros/src/agitr/src$
```

Example Client Program to Use Services

`/clear, /turtle1/set_pen, /turtle1/teleport_absolute`

Edit useservices.cpp and insert the following code

```
/* This client program uses a sample of turtlesim services */
/* /clear, /turtle1/set_pen, and /turtle1/telepor_absolute */

#include <ros/ros.h>
#include <turtlesim/TeleportAbsolute.h> // for turtle1/teleport_absolute service
#include <turtlesim/SetPen.h>           // for turtle1/set_pen service
#include <std_srvs/Empty.h>             // for reset and clear services

int main(int argc, char **argv) {

   bool success = true;

   /* Initialize the ROS system and become a node */
   ros::init(argc, argv, "mystudentid"); // Initialize the ROS system
   ros::NodeHandle nh;                   // Become a node

   /* Create client objects for the required services */
   ros::service::waitForService("turtle1/teleport_absolute");
   ros::ServiceClient teleportClient = nh.serviceClient<turtlesim::TeleportAbsolute>("turtle1/teleport_absolute");

   ros::service::waitForService("turtle1/set_pen");
   ros::ServiceClient setpenClient = nh.serviceClient<turtlesim::SetPen>("turtle1/set_pen");

   ros::service::waitForService("clear");
   ros::ServiceClient clearClient = nh.serviceClient<std_srvs::Empty>("clear");
```

`waitForService()` waits for a service to be advertised and available. Block until it is. This is defensive programming; normally it works without it.

Example Client Program to Use Services

/clear, /turtle1/set_pen, /turtle1/teleport_absolute

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/* /clear, /turtle1/set_pen, and /turtle1/telepor_absolute */

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   /* Create client objects for the required services */
   ros::service::waitForService("turtle1/teleport_absolute");
   ros::ServiceClient teleportClient = nh.serviceClient<turtlesim::TeleportAbsolute>("turtle1/teleport_absolute");

   ros::service::waitForService("turtle1/set_pen");
   ros::ServiceClient setpenClient = nh.serviceClient<turtlesim::SetPen>("turtle1/set_pen");

   ros::service::waitForService("clear");
   ros::ServiceClient clearClient = nh.serviceClient<std_srvs::Empty>("clear");
```

You need to identify the service type when creating the client object

Example Client Program to Use Services

`/clear, /turtle1/set_pen, /turtle1/teleport_absolute`

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   ros::service::waitForService("turtle1/set_pen");
   ros::ServiceClient setpenClient = nh.serviceClient<turtlesim::SetPen>("turtle1/set_pen");

   ros::service::waitForService("clear");
   ros::ServiceClient clearClient = nh.serviceClient<std_srvs::Empty>("clear");
```

The service types are defined in these include files

Example Client Program to Use Services

`/clear, /turtle1/set_pen, /turtle1/teleport_absolute`

Edit useservices.cpp and insert the following code

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/* /clear, /turtle1/set_pen, and /turtle1/telepor_absolute */

#include <ros/ros.h>
#include <turtlesim/TeleportAbsolute.h> // for turtle1/teleport_absolute service
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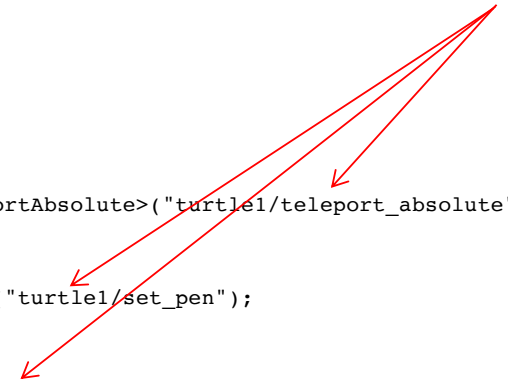
   ros::service::waitForService("turtle1/teleport_absolute");
   ros::ServiceClient teleportClient = nh.serviceClient<turtlesim::TeleportAbsolute>("turtle1/teleport_absolute");

   ros::service::waitForService("turtle1/set_pen");
   ros::ServiceClient setpenClient = nh.serviceClient<turtlesim::SetPen>("turtle1/set_pen");

   ros::service::waitForService("clear");
   ros::ServiceClient clearClient = nh.serviceClient<std_srvs::Empty>("clear");
```

You also need to define a string naming the service you want to call



Example Client Program to Use Services

/clear, /turtle1/set_pen, /turtle1/teleport_absolute

```
/* Create the service objects services */
turtlesim::TeleportAbsolute teleport_arguments; // reposition the turtle without locomotion
turtlesim::SetPen           pen_arguments;      // turn the pen on/off and change colour
std_srvs::Empty             clear_arguments;    // clear the background

/* clear the simulator background */
success = clearClient.call(clear_arguments);
if (!success) {
   ROS_ERROR_STREAM("Turtle failed to clear" );
}

/* turn the pen off so that we don't see a trace when the turtle teleports */
pen_arguments.request.off = 1;
success = setpenClient.call(pen_arguments);
if (!success) {
   ROS_ERROR_STREAM("TurtlePen failed to switch off");
}

teleport_arguments.request.x     = 2.5;         // location
teleport_arguments.request.y     = 3.5;         // coordinates
teleport_arguments.request.theta = 3.14159 / 2; // facing up, i.e. 90 degrees

success = teleportClient.call(teleport_arguments);
if (!success) {
   ROS_ERROR_STREAM("Turtle failed to teleport" );
}
```

We instantiate the service classes as service objects so that we can assign values to the request members

Example Client Program to Use Services

/clear, /turtle1/set_pen, /turtle1/teleport_absolute

```
/* Create the service objects services */
turtlesim::TeleportAbsolute teleport_arguments; // reposition the turtle without locomotion
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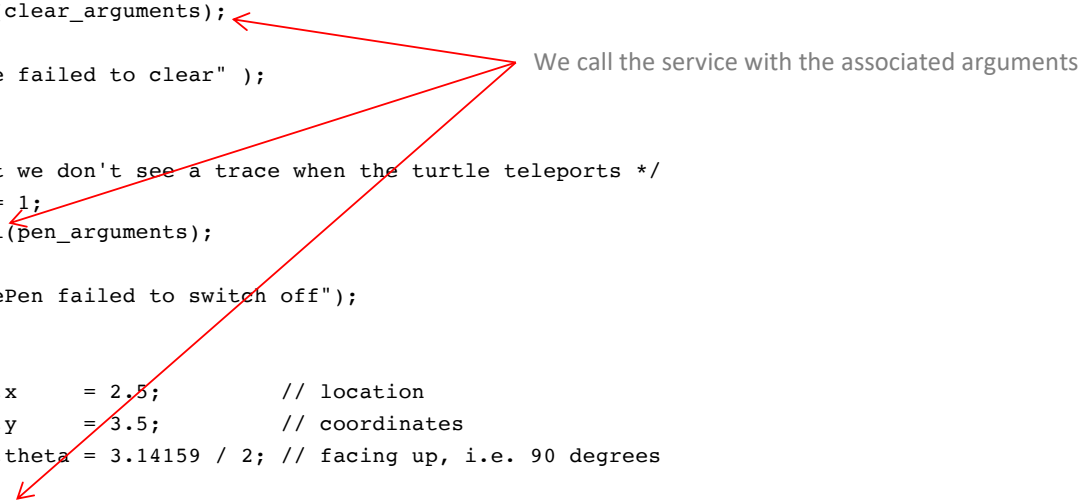
/* clear the simulator background */
success = clearClient.call(clear_arguments);
if (!success) {
   ROS_ERROR_STREAM("Turtle failed to clear" );
}

/* turn the pen off so that we don't see a trace when the turtle teleports */
pen_arguments.request.off = 1;
success = setpenClient.call(pen_arguments);
if (!success) {
   ROS_ERROR_STREAM("TurtlePen failed to switch off");
}

teleport_arguments.request.x     = 2.5;         // location
teleport_arguments.request.y     = 3.5;         // coordinates
teleport_arguments.request.theta = 3.14159 / 2; // facing up, i.e. 90 degrees

success = teleportClient.call(teleport_arguments);
if (!success) {
   ROS_ERROR_STREAM("Turtle failed to teleport" );
}
```



Example Client Program to Use Services

/clear, /turtle1/set_pen, /turtle1/teleport_absolute

```
/* Create the service objects services */
turtlesim::TeleportAbsolute teleport_arguments; // reposition the turtle without locomotion
turtlesim::SetPen           pen_arguments;      // turn the pen on/off and change colour
std_srvs::Empty             clear_arguments;    // clear the background

/* clear the simulator background */
success = clearClient.call(clear_arguments);
if (!success) {
   ROS_ERROR_STREAM("Turtle failed to clear" );
}

/* turn the pen off so that we don't see a trace when the turtle teleports */
pen_arguments.request.off = 1;
success = setpenClient.call(pen_arguments);
if (!success) {
   ROS_ERROR_STREAM("TurtlePen failed to switch off");
}

teleport_arguments.request.x     = 2.5;         // location
teleport_arguments.request.y     = 3.5;         // coordinates
teleport_arguments.request.theta = 3.14159 / 2; // facing up, i.e. 90 degrees

success = teleportClient.call(teleport_arguments);
if (!success) {
   ROS_ERROR_STREAM("Turtle failed to teleport");
}
```

Check to ensure the service call was successful and report an error if not

Example Client Program to Use Services

/clear, /turtle1/set_pen, /turtle1/teleport_absolute

```
   /* turn the pen again so that we do see a trace when the turtle moves later on */
   pen_arguments.request.off    = 0;
   pen_arguments.request.r      = 255; // white
   pen_arguments.request.g      = 255; // pen
   pen_arguments.request.b      = 255; // colour
   pen_arguments.request.width = 1;    // narrow line

   success = setpenClient.call(pen_arguments);
   if (!success) {
      ROS_ERROR_STREAM("TurtlePen failed to switch on");
   }
}
```

Example Client Program to Use Services

`/clear, /turtle1/set_pen, /turtle1/teleport_absolute`

Build the workspace to compile the program

- Make sure you are in the workspace directory

```
~/workspace/ros/src/agitr/src$ cd ~/workspace/ros
~/workspace/rosr$
```

- Run catkin_make

```
~/workspace/ros$ catkin_make
```

Example Client Program to Use Services

`/clear, /turtle1/set_pen, /turtle1/teleport_absolute`

If you have not already done it, open a terminal and enter

```
~$ roscore
```

If you have not already done it, open a second terminal and enter

```
~$ rosrun turtlesim turtlesim_node
```

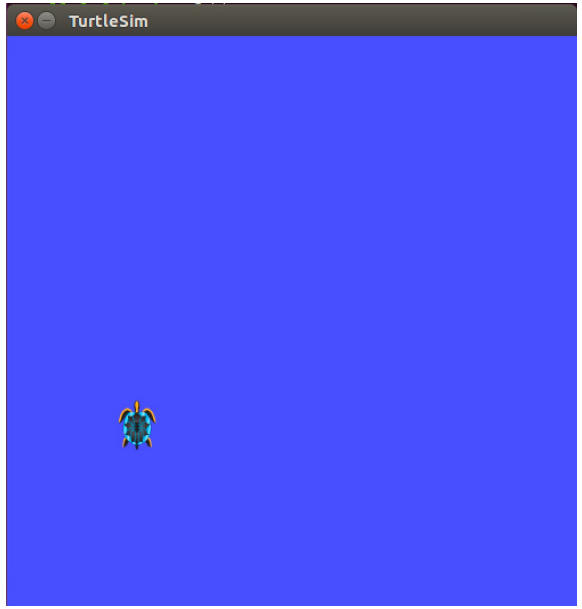
Open a third terminal and enter

```
~$ rosrun agitr useservices
```

Example Client Program to Use Services

`/reset, /clear, /turtle1/set_pen, /turtle1/teleport_absolute`

If everything works correctly, you should see the following



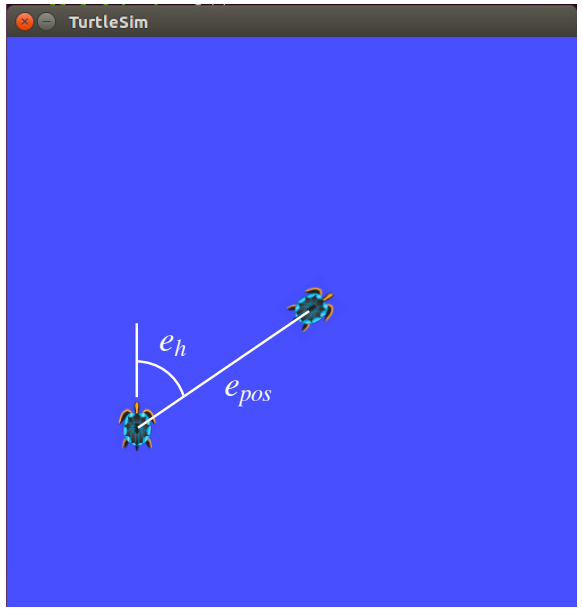
Move the turtle to a given location

- Back to this question: how would we move the turtle to a given location?
- We now know how to determine the current location of the turtle
- So now we just have to decide what velocity commands to publish change the position
- We will use the following algorithm

Move the turtle to a given location

- Given the turtle's current position
  - (x_r, y_r, θ_r)
- Given the position of the goal
  - (x_g, y_g)
- Compute error in position and heading
  - (e_{pos}, e_h)
- Reduce both errors to zero
  - by generating the appropriate forward and angular velocities (v, ω)

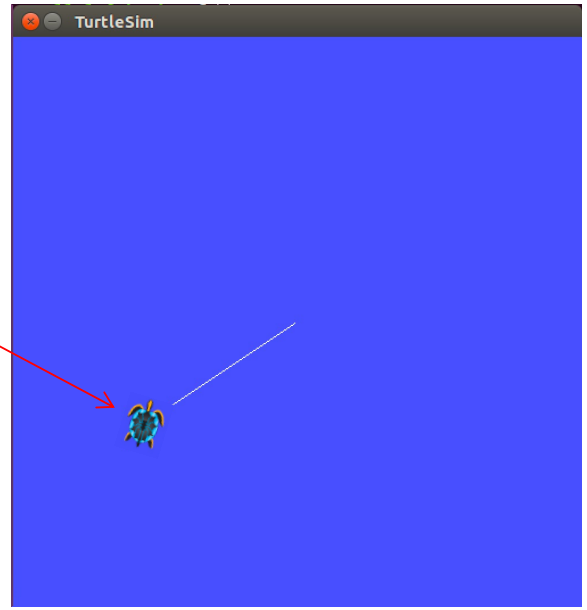
Move the turtle to a given location



Move the turtle to a given location

Move the turtle to a given location

Publish non-zero angular velocity
until error in heading is ~zero



Move the turtle to a given location

Publish non-zero angular velocity
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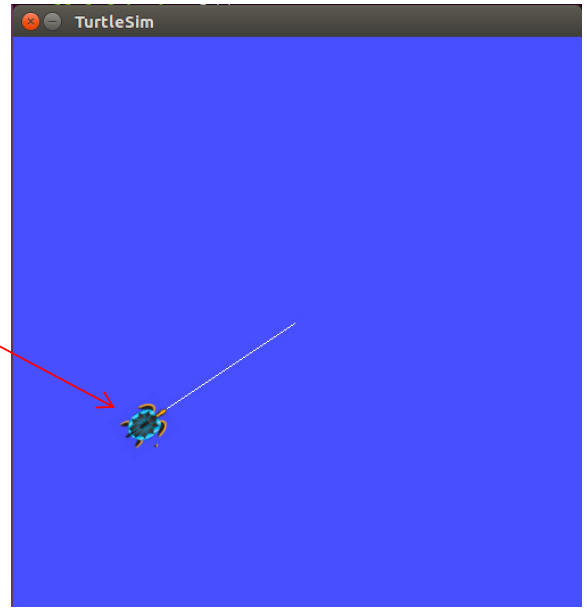
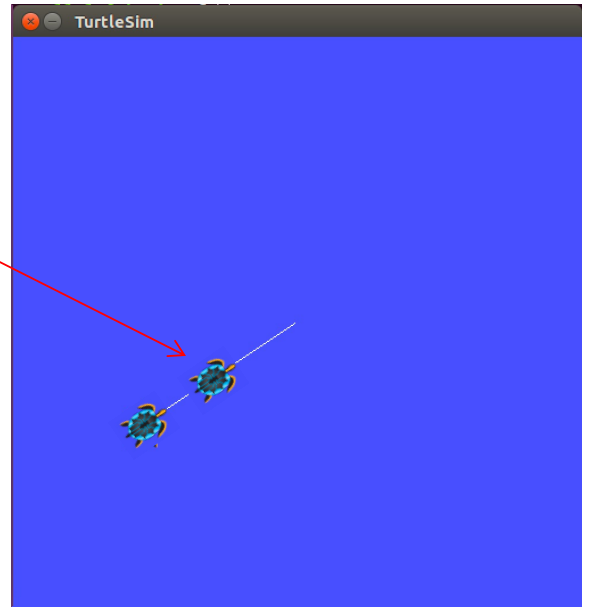


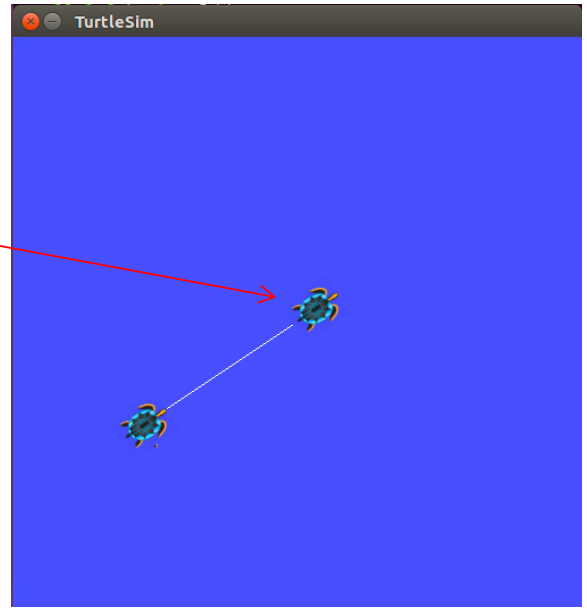
Move the turtle to a given location

Publish non-zero forward velocity
until error in position is ~zero



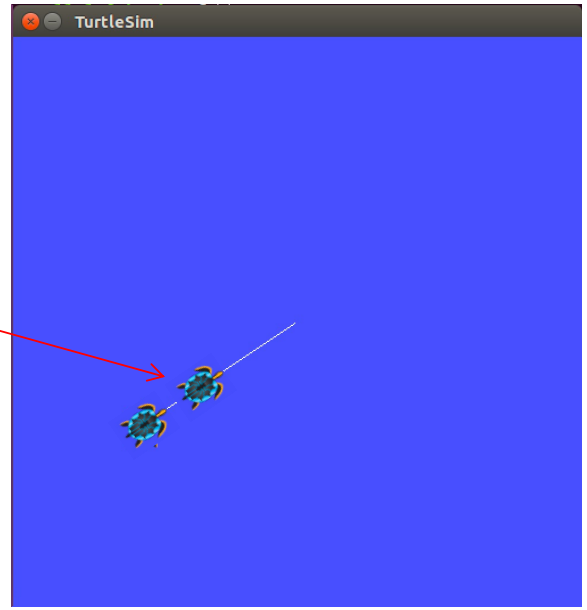
Move the turtle to a given location

Publish non-zero forward velocity
until error in position is ~zero



Move the turtle to a given location

Publish non-zero angular velocity if the heading error exceeds some tolerance



Move the turtle to a given location

Decompose 2D problem into two 1D problems (divide and conquer)

- First, correct the heading:

  rotate to reduce the orientation error to zero

- Second, correct the position:

  translate straight ahead to reduce the position error to zero

Move the turtle to a given location

do

Compute the current position of the robot (x_r, y_r)

Compute the distances from the robot position to the target position (d_x, dy)

$d_x = x_g - x_r$

$d_y = y_g - y_r$

Compute the position and heading errors(e_{pos}, e_h)

$e_{pos} = \text{sqrt}\ (d_x^2 + d_y^2)$

$e_h = \text{atan2}\ (d_y, d_x) - \theta_r$

The difference between the desired heading and the current robot orientation

If not oriented correctly, correct heading

if $|e_h| > \Delta_h$ — tolerance on error in heading

Otherwise, correct position

set forward velocity: $v = 0$

set angular velocity: $\omega = K_p^h\ e_h$

constant gain to control correction in heading error

else

constant gain to control correction in position error

set forward velocity: $v = K_p^{pos}\ e_{pos}$

set angular velocity: $\omega = 0$

or some maximum velocity v_{max}

Send velocities (v, ω) to the robot

Pause some time

while $|e_{pos}| > \Delta_{pos}$ — tolerance on error in position

Send velocities $(0, 0)$ to the robot

ROS Resources

Wiki	http://wiki.ros.org/
Installation	http://wiki.ros.org/ROS/Installation
Tutorials	http://wiki.ros.org/ROS/Tutorials
Tutorial Videos	http://www.youtube.com/playlist?list=PLDC89965A56E6A8D6
ROS Cheat Sheet	http://www.tedusar.eu/files/summerschool2013/ROScheatsheet.pdf

Recommended Reading

http://wiki.ros.org/catkin/Tutorials/create_a_workspace

http://wiki.ros.org/ROS/Tutorials/CreatingPackage

http://wiki.ros.org/roscpp/Overview/InitializationandShutdown

http://wiki.ros.org/roscpp/Overview/NodeHandles

http://wiki.ros.org/ROS/Tutorials/BuildingPackages

http://wiki.ros.org/ROS/Tutorials/WritingPublisherSubscriber(c++)

J. M. O'Kane, A Gentle Introduction to ROS, 2014.
https://cse.sc.edu/~jokane/agitr/