Introduction to Cognitive Robotics

Module 2: The Robot Operating System (ROS)
Lecture 2: Writing ROS software in C++

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Lecture 5

Mobile Robots: ROS

- Introduction to ROS (Robot Operating System)

  (Rhymes with “gloss”)

- Introduction to writing ROS software
  - Using the ROS Turtlebot simulator `Turtlesim`
  - Here in C++
  - Later in the course in Lisp with CRAM

Based mainly on J. M. O’Kane, *A Gentle Introduction to ROS*, 2014.
`https://cse.sc.edu/~jokane/agitr/`

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`

   3. Example program to subscribe to messages

      Receive pose messages on `/turtle1/pose`

Writing ROS Software

- Writing ROS programs

4. Example program to use services

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

Creating a ROS workspace

- We first create a ROS workspace and then create our packages in that workspace
- We will refer to is as the workspace directory
- We will create it in the home directory
- We can name the directory anything we wish but,
  to be consistent with the CRAM examples later in the course,
  we will name it ~/workspace/ros

This is not necessary if you have installed CRAM because it is done automatically during the CRAM installation

Creating a ROS workspace

Create a ROS workspace

- We also need to create a src sub-directory in the workspace directory
- We can do all this in one step:

```
~$ mkdir -p ~/workspace/ros/src
```

This is not necessary if you have installed CRAM because it is done automatically during the CRAM installation

The -p causes the creation of three directories:
/workspace
/workspace/ros
/workspace/ros/src

Creating a ROS package

Create a package for the example programs

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

The second argument identifies a dependency on roscpp
Other dependencies can be specified by additional arguments

We name the package agitr because these examples are based on A Gentle Introduction to ROS by J. M. O'Kane

This creates

- a directory agitr to hold the package, containing the following files
- package.xml a configuration file containing the manifest we discussed earlier
- CMakeLists.txt a script for CMake, an industrial-strength build system used by ROS
- and the following sub-directories src and include

Creating a ROS package

Make sure you are in the agitr sub-directory

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

Creating a ROS package

Edit package.xml

- Use your preferred editor, e.g. vi or emacs
  - Later in the course, we will be using emacs extensively with CRAM
  - Perhaps this is a good time to become familiar with it
  - There is an introduction to Emacs in Lecture CR08-03
- Non-essential edits:
  - Update the description
  - Update the name and email of the maintainer

Example Program: Hello World!

Edit CMakeLists.txt

Add the following lines at the end of the file

```
add_executable(${PROJECT_NAME}_hello src/hello.cpp)
set_target_properties(${PROJECT_NAME}_hello PROPERTIES OUTPUT_NAME hello  PREFIX "")
target_link_libraries(${PROJECT_NAME}_hello ${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 hello

Example Program: Hello World!

- Move to the agitr/src sub-directory

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

- Edit hello.cpp and insert the following code

```
/* This is a ROS version of the standard "Hello , World" program */

#include <ros/ros.h>                      // This header defines the standard ROS classes

int main(int argc, char **argv) {
   ros::init(argc, argv, "hello_world");  // Initialize the ROS system
   ros::NodeHandle nh;                    // Register this program as a ROS node
   ROS_INFO_STREAM("Hello World!");       // Send some output as a log message
}
```

This is the name of your node

Example Program: Hello World!

Build the workspace to compile the program

- Because catkin builds all of the packages in the workspace directory, first make sure you are in the workspace directory

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

or, simply

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

Example Program: Hello World!

Build the workspace to compile the program

- Run catkin_make

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

- Add the workspace to your ROS environment by sourcing the generated setup file

```
~/workspace/ros$ source devel/setup.bash
```

- Add the setup to your .bashrc file so that you don't have to do this every time you open a new terminal

```
~/workspace/ros$ echo "source $HOME/workspace/ros/devel/setup.bash" >> ~/.bashrc
```

Example Program: Hello World!

Run the ROS master

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

```
~$ roscore
```

Now, use rosrun to execute the program

Open a second terminal and enter

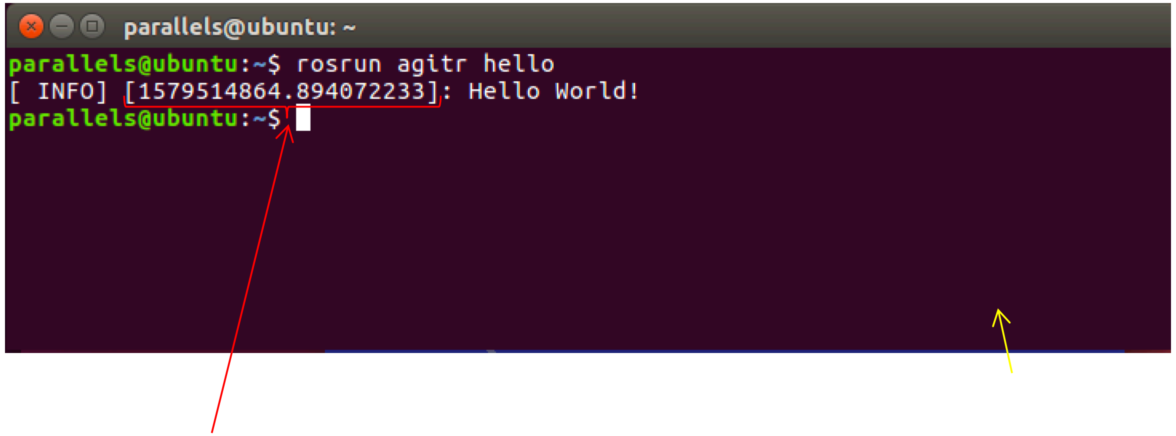
```
~/workspace/ros$ rosrun agitr hello
```

This is the name of your package

This is the name of your program

Example Program: Hello World!

If everything works correctly, you should see a message printed to the terminal



```
parallels@ubuntu:~$ rosrun agitr hello
[ INFO] [1579514864.894072233]: Hello World!
parallels@ubuntu:~$ 
```

This is the time, measured in seconds since January 1, 1970

Example Program to Publish Messages

Send velocity messages on `/turtle1/cmd_vel`

Make sure you are in the agitr sub-directory

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

Or, better

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

Example Program to Publish Messages

Send velocity messages on `/turtle1/cmd_vel`

Edit CMakeLists.txt

Add the following lines at the end of the file

```
add_executable(${PROJECT_NAME}_pubvel src/pubvel.cpp)
set_target_properties(${PROJECT_NAME}_pubvel PROPERTIES OUTPUT_NAME pubvel  PREFIX "")
target_link_libraries(${PROJECT_NAME}_pubvel ${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 pubvel

Example Program to Publish Messages

Send velocity messages on `/turtle1/cmd_vel`

Move to the agitr/src sub-directory

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

Example Program to Publish Messages

Send velocity messages on `/turtle1/cmd_vel`

Edit pubvel.cpp and insert the following code

```
/* This program publishes randomly-generated velocity messages for turtlesim */

#include <ros/ros.h>
#include <geometry_msgs/Twist.h> // For geometry_msgs::Twist
#include <stdlib.h>              // For rand() and RAND_MAX

int main(int argc , char **argv) {
   ros::init(argc, argv, "publish_velocity"); // Initialize the ROS system
   ros::NodeHandle nh;                        // Become a node
   ros::Publisher pub = nh.advertise<geometry_msgs::Twist>("turtle1/cmd_vel", 1000);
   srand(time(0));    // Seed the random number generator
   ros::Rate rate(2); // Loop at 2Hz until the node is shut down

   while(ros::ok()) {

      geometry_msgs::Twist msg;                                    // Create the message
      msg.linear.x  = double(rand())/double(RAND_MAX);             // fill in the fields
      msg.angular.z = 2*3.14159*double(rand())/double(RAND_MAX)-1; // other fields default to 0
      pub.publish(msg);                                            // Publish the message

      /* Send a message to rosout with the details */
      ROS_INFO_STREAM("Sending random velocity command:" << " linear =" << msg.linear.x << " angular =" << msg.angular.z);
      rate.sleep(); // Wait until it's time for another iteration
   }
}
```

Example Program to Publish Messages

Send velocity messages on `/turtle1/cmd_vel`

Edit pubvel.cpp and insert the following code

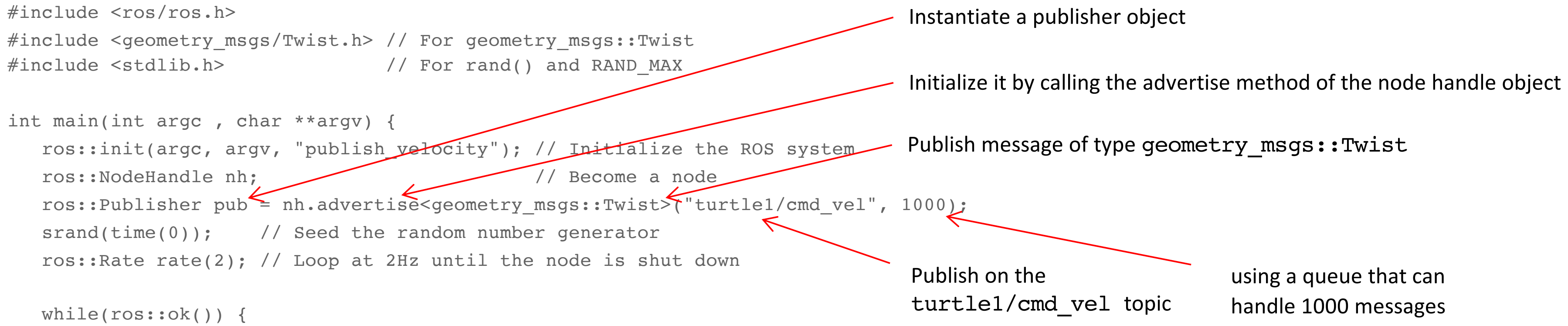
`Twist` type in the `geometry_msgs` package is used to instantiate a message

```
/* This program publishes randomly-generated velocity messages for turtlesim */

#include <ros/ros.h>
#include <geometry_msgs/Twist.h> // For geometry_msgs::Twist
#include <stdlib.h>              // For rand() and RAND_MAX

int main(int argc , char **argv) {
   ros::init(argc, argv, "publish_velocity"); // Initialize the ROS system
   ros::NodeHandle nh;                        // Become a node
   ros::Publisher pub = nh.advertise<geometry_msgs::Twist>("turtle1/cmd_vel", 1000);
   srand(time(0));    // Seed the random number generator
   ros::Rate rate(2); // Loop at 2Hz until the node is shut down

   while(ros::ok()) {

      geometry_msgs::Twist msg;                                    // Create the message
      msg.linear.x  = double(rand())/double(RAND_MAX);             // fill in the fields
      msg.angular.z = 2*3.14159*double(rand())/double(RAND_MAX)-1; // other fields default to 0
      pub.publish(msg);                                            // Publish the message

      /* Send a message to rosout with the details */
      ROS_INFO_STREAM("Sending random velocity command:" << " linear =" << msg.linear.x << " angular =" << msg.angular.z);
      rate.sleep(); // Wait until it's time for another iteration
   }
}
```

Example Program to Publish Messages

Send velocity messages on `/turtle1/cmd_vel`

Edit pubvel.cpp and insert the following code



```
/* This program publishes randomly-generated velocity messages for turtlesim */

#include <ros/ros.h>
#include <geometry_msgs/Twist.h> // For geometry_msgs::Twist
#include <stdlib.h>              // For rand() and RAND_MAX

int main(int argc , char **argv) {
   ros::init(argc, argv, "publish_velocity"); // Initialize the ROS system
   ros::NodeHandle nh;                        // Become a node
   ros::Publisher pub = nh.advertise<geometry_msgs::Twist>("turtle1/cmd_vel", 1000);
   srand(time(0));    // Seed the random number generator
   ros::Rate rate(2); // Loop at 2Hz until the node is shut down

   while(ros::ok()) {

      geometry_msgs::Twist msg;                               // Create the message
      msg.linear.x  = double(rand())/double(RAND_MAX);        // fill in the fields
      msg.angular.z = 2*3.14159*double(rand())/double(RAND_MAX)-1; // other fields default to 0
      pub.publish(msg);                                       // Publish the message

      /* Send a message to rosout with the details */
      ROS_INFO_STREAM("Sending random velocity command:" << " linear =" << msg.linear.x << " angular =" << msg.angular.z);
      rate.sleep(); // Wait until it's time for another iteration
   }
}
```

Instantiate a publisher object

Initialize it by calling the advertise method of the node handle object

Publish message of type `geometry_msgs::Twist`

Publish on the `turtle1/cmd_vel` topic

using a queue that can handle 1000 messages

Example Program to Publish Messages

Send velocity messages on `/turtle1/cmd_vel`

Edit pubvel.cpp and insert the following code

```
/* This program publishes randomly-generated velocity messages for turtlesim */

#include <ros/ros.h>
#include <geometry_msgs/Twist.h> // For geometry_msgs::Twist
#include <stdlib.h>              // For rand() and RAND_MAX

int main(int argc , char **argv) {
   ros::init(argc, argv, "publish_velocity"); // Initialize the ROS system
   ros::NodeHandle nh;                        // Become a node
   ros::Publisher pub = nh.advertise<geometry_msgs::Twist>("turtle1/cmd_vel", 1000);
   srand(time(0));    // Seed the random number generator
   ros::Rate rate(2); // Loop at 2Hz until the node is shut down

   while(ros::ok()) {

      geometry_msgs::Twist msg;                                    // Create the message
      msg.linear.x  = double(rand())/double(RAND_MAX);             // fill in the fields
      msg.angular.z = 2*double(rand())/double(RAND_MAX)-1;         // other fields default to 0
      pub.publish(msg);                                            // Publish the message

      /* Send a message to rosout with the details */
      ROS_INFO_STREAM("Sending random velocity command:" << " linear =" << msg.linear.x << " angular =" << msg.angular.z);
      rate.sleep(); // Wait until it's time for another iteration
   }
}
```

Instantiate a `rate` object of the `ros::Rate` class to control how often the messages are published

Example Program to Publish Messages

Send velocity messages on `/turtle1/cmd_vel`

Edit pubvel.cpp and insert the following code

```
/* This program publishes randomly-generated velocity messages for turtlesim */

#include <ros/ros.h>
#include <geometry_msgs/Twist.h> // For geometry_msgs::Twist
#include <stdlib.h>              // For rand() and RAND_MAX

int main(int argc , char **argv) {
   ros::init(argc, argv, "publish_velocity"); // Initialize the ROS system
   ros::NodeHandle nh;                        // Become a node
   ros::Publisher pub = nh.advertise<geometry_msgs::Twist>("turtle1/cmd_vel", 1000);
   srand(time(0));    // Seed the random number generator
   ros::Rate rate(2); // Loop at 2Hz until the node is shut down

   while(ros::ok()) {

      geometry_msgs::Twist msg;                                    // Create the message
      msg.linear.x  = double(rand())/double(RAND_MAX);             // fill in the fields
      msg.angular.z = 2*double(rand())/double(RAND_MAX)-1;         // other fields default to 0
      pub.publish(msg);                                            // Publish the message

      /* Send a message to rosout with the details */
      ROS_INFO_STREAM("Sending random velocity command:" << " linear =" << msg.linear.x << " angular =" << msg.angular.z);
      rate.sleep(); // Wait until it's time for another iteration
   }
}
```

Loop, sending messages, while `ros::ok()` returns `true`
(it will return `false` if you use `rosnode kill` on the node,
or send an interrupt signal `cntrl-C`,
or if the program calls `ros::shutdown()` to terminate itself)

Example Program to Publish Messages

Send velocity messages on `/turtle1/cmd_vel`

Edit pubvel.cpp and insert the following code

```
/* This program publishes randomly-generated velocity messages for turtlesim */

#include <ros/ros.h>
#include <geometry_msgs/Twist.h> // For geometry_msgs::Twist
#include <stdlib.h>              // For rand() and RAND_MAX

int main(int argc , char **argv) {
   ros::init(argc, argv, "publish_velocity"); // Initialize the ROS system
   ros::NodeHandle nh;                        // Become a node
   ros::Publisher pub = nh.advertise<geometry_msgs::Twist>("turtle1/cmd_vel", 1000);
   srand(time(0));    // Seed the random number generator
   ros::Rate rate(2); // Loop at 2Hz until the node is shut down

   while(ros::ok()) {

      geometry_msgs::Twist msg;                               // Create the message
      msg.linear.x  = double(rand())/double(RAND_MAX);        // fill in the fields
      msg.angular.z = 2*double(rand())/double(RAND_MAX)-1;    // other fields default to 0
      pub.publish(msg);                                       // Publish the message

      /* Send a message to rosout with the details */
      ROS_INFO_STREAM("Sending random velocity command:" << " linear =" << msg.linear.x << " angular =" << msg.angular.z);
      rate.sleep(); // Wait until it's time for another iteration
   }
}
```

Set the linear velocity between 0 and 2

Set the angular velocity to a number between -1 and 1

`msg.linear.y`
`msg.linear.z`
`msg.angular.x`
`msg.angular.y`
`are given their`
`default values of zero`

Example Program to Publish Messages

Send velocity messages on `/turtle1/cmd_vel`

Edit pubvel.cpp and insert the following code

```
/* This program publishes randomly-generated velocity messages for turtlesim */

#include <ros/ros.h>
#include <geometry_msgs/Twist.h> // For geometry_msgs::Twist
#include <stdlib.h>              // For rand() and RAND_MAX

int main(int argc , char **argv) {
   ros::init(argc, argv, "publish_velocity"); // Initialize the ROS system
   ros::NodeHandle nh;                        // Become a node
   ros::Publisher pub = nh.advertise<geometry_msgs::Twist>("turtle1/cmd_vel", 1000);
   srand(time(0));    // Seed the random number generator
   ros::Rate rate(2); // Loop at 2Hz until the node is shut down

   while(ros::ok()) {

      geometry_msgs::Twist msg;                                     // Create the message
      msg.linear.x  = double(rand())/double(RAND_MAX);              // fill in the fields
      msg.angular.z = 2*double(rand())/double(RAND_MAX)-1;          // other fields default to 0
      pub.publish(msg);                                             // Publish the message

      /* Send a message to rosout with the details */
      ROS_INFO_STREAM("Sending random velocity command:" << " linear =" << msg.linear.x << " angular =" << msg.angular.z);
      rate.sleep(); // Wait until it's time for another iteration
   }
}
```

Each call to this method causes a delay in the program. The duration of the delay is calculated to ensure the loop iterates at the required rate (in this case 2 Hz)

Example Program to Publish Messages

Send velocity messages on `/turtle1/cmd_vel`

Build the workspace to compile the program

- Make sure you are in the workspace directory

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

- Run catkin_make

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

Example Program to Publish Messages

Send velocity messages on `/turtle1/cmd_vel`

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

```
~$ roscore
```

Open a second terminal and enter

```
~$ rosrun turtlesim turtlesim_node
```

Open a third terminal and enter

```
~$ rosrun agitr pubvel
```

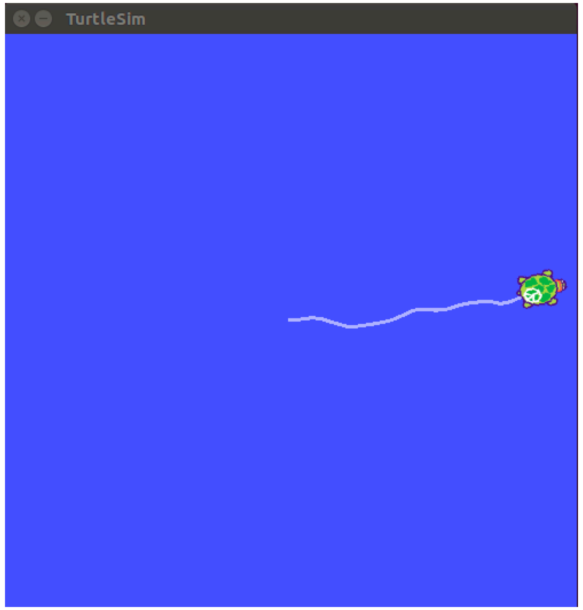
The separate terminals are intended to allow all three commands to execute simultaneously

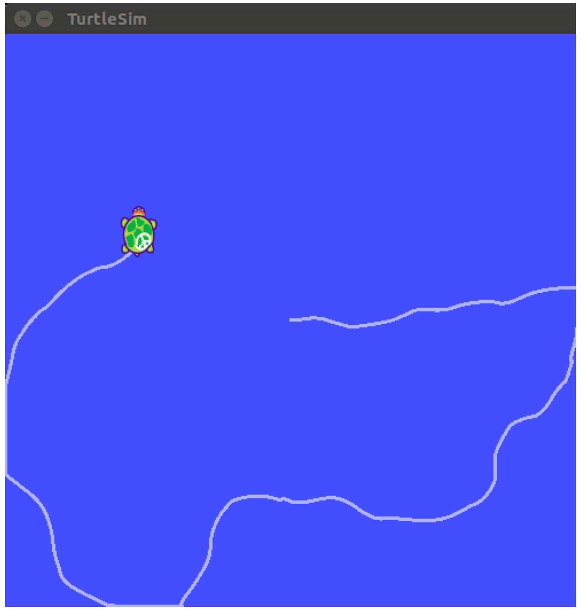
Example Program to Publish Messages

Send velocity messages on `/turtle1/cmd_vel`

If everything works correctly, you should see a graphical window similar to those below with the turtle moving randomly around

Again, the appearance of your turtle may differ. The simulator selects from a collection of “mascot” turtles for each of the historical distributions of ROS





Example Program to Subscribe to Messages

Receive pose messages on `/turtle1/pose`

Make sure you are in the **agitr** sub-directory

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

Example Program to Subscribe to Messages

Receive pose messages on `/turtle1/pose`

Edit CMakeLists.txt

Add the following lines at the end of the file

```
add_executable(${PROJECT_NAME}_subpose src/subpose.cpp)
set_target_properties(${PROJECT_NAME}_subpose PROPERTIES OUTPUT_NAME subpose  PREFIX "")
target_link_libraries(${PROJECT_NAME}_subpose ${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 subpose

Example Program to Subscribe to Messages

Receive pose messages on `/turtle1/pose`

Move to the agitr/src sub-directory

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

Example Program to Subscribe to Messages

Receive pose messages on `/turtle1/pose`

Edit subpose.cpp and insert the following code

```cpp
/* This program subscribes to turtle1/pose and shows its messages on the screen */

#include <ros/ros.h>
#include <turtlesim/Pose.h>
#include <iomanip> // for std::setprecision and std::fixed

/* A callback function. Executed each time a new pose message arrives */
void poseMessageReceived(const turtlesim::Pose& msg) {
   ROS_INFO_STREAM(std::setprecision(2) << std::fixed <<
                "position=(" << msg.x << "," << msg.y << ")" <<
                " direction=" << msg.theta);
}

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

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

   /* Create a subscriber object */
   ros::Subscriber sub = nh.subscribe("turtle1/pose", 1000, &poseMessageReceived);

   /* Let ROS take over */
   ros::spin();
}
```

Example Program to Subscribe to Messages

Receive pose messages on `/turtle1/pose`

Edit subpose.cpp and insert the following code

```
/* This program subscribes to turtle1/pose and shows its messages on the screen */

#include <ros/ros.h>
#include <turtlesim/Pose.h>
#include <iomanip> // for std::setprecision and std::fixed

/* A callback function. Executed each time a new pose message arrives */
void poseMessageReceived(const turtlesim::Pose& msg) {
   ROS_INFO_STREAM(std::setprecision(2) << std::fixed <<
                 "position=(" << msg.x << "," << msg.y << ")" <<
                 " direction=" << msg.theta);
}

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

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

   /* Create a subscriber object */
   ros::Subscriber sub = nh.subscribe("turtle1/pose", 1000, &poseMessageReceived);

   /* Let ROS take over */
   ros::spin();
}
```

The callback function is called every time a message is received
We have to put the code to handle the message in this function

The parameter is the message that arrives.
The type of the message is defined in the header file `<turtlesim/Pose.h>`

Here, we simply print the values to the terminal

Example Program to Subscribe to Messages

Receive pose messages on `/turtle1/pose`

Edit subpose.cpp and insert the following code

```
/* This program subscribes to turtle1/pose and shows its messages on the screen */

#include <ros/ros.h>
#include <turtlesim/Pose.h>
#include <iomanip> // for std::setprecision and std::fixed

/* A callback function. Executed each time a new pose message arrives */
void poseMessageReceived(const turtlesim::Pose& msg) {
   ROS_INFO_STREAM(std::setprecision(2) << std::fixed <<
                 "position=(" << msg.x << "," << msg.y << ")" <<
                 " direction=" << msg.theta);
}

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

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

   /* Create a subscriber object */
   ros::Subscriber sub = nh.subscribe("turtle1/pose", 1000, &poseMessageReceived);

   /* Let ROS take over */
   ros::spin();
}
```

Instantiate a subscriber object

Initialize it by calling the subscribe method of the node handle object

Subscribe on the `turtle1/pose` topic

using a queue that can handle 1000 messages

Pass a pointer to the callback function that is to be called when messages arrive

Example Program to Subscribe to Messages

Receive pose messages on `/turtle1/pose`

Edit subpose.cpp and insert the following code

```
/* This program subscribes to turtle1/pose and shows its messages on the screen */

#include <ros/ros.h>
#include <turtlesim/Pose.h>
#include <iomanip> // for std::setprecision and std::fixed

/* A callback function. Executed each time a new pose message arrives */
void poseMessageReceived(const turtlesim::Pose& msg) {
   ROS_INFO_STREAM(std::setprecision(2) << std::fixed <<
                "position=(" << msg.x << "," << msg.y << ")" <<
                " direction=" << msg.theta);
}

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

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

   /* Create a subscriber object */
   ros::Subscriber sub = nh.subscribe("turtle1/pose", 1000, &poseMessageReceived);

   /* Let ROS take over */
   ros::spin();
}
```

Allow ROS to service the callback by calling `ros::spin()`

Note: won't return control to this main() function; it will just carry on servicing the call the callback function

If you want to do more work here, call `ros::spinOnce()`

This will allow ROS to execute all pending callback calls and then return control to here

You'll probably embed this call in a loop so that you iteratively service the callback and then do some work

Example Program to Subscribe to Messages

Receive pose messages on `/turtle1/pose`

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 Program to Subscribe to Messages

Receive pose messages on `/turtle1/pose`

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
```

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

```
~$ rosrun agitr pubvel
```

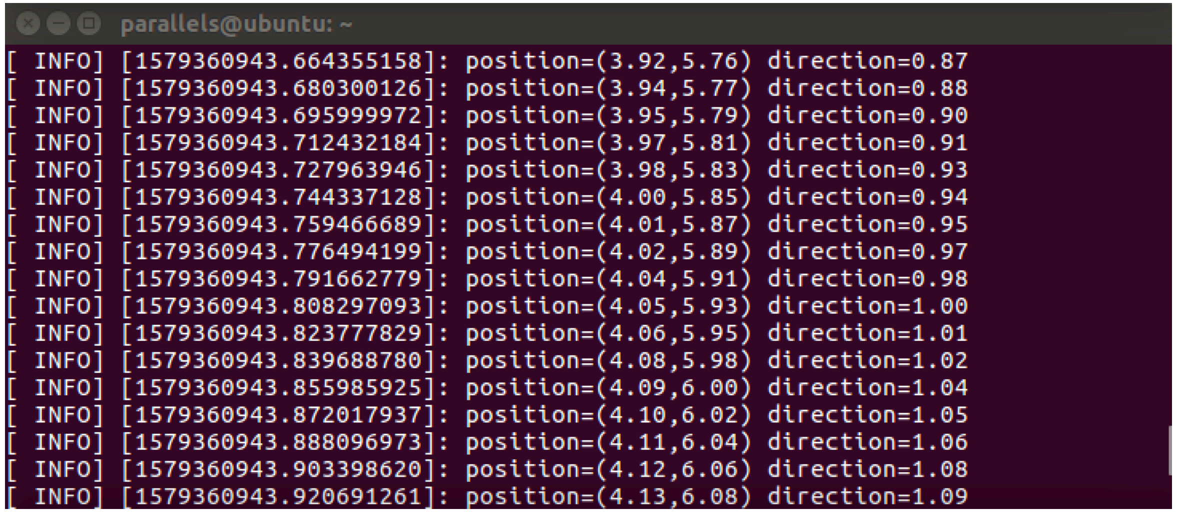
Open a fourth terminal and enter

```
~$ rosrun agitr subpose
```

Example Program to Subscribe to Messages

Receive pose messages on `/turtle1/pose`

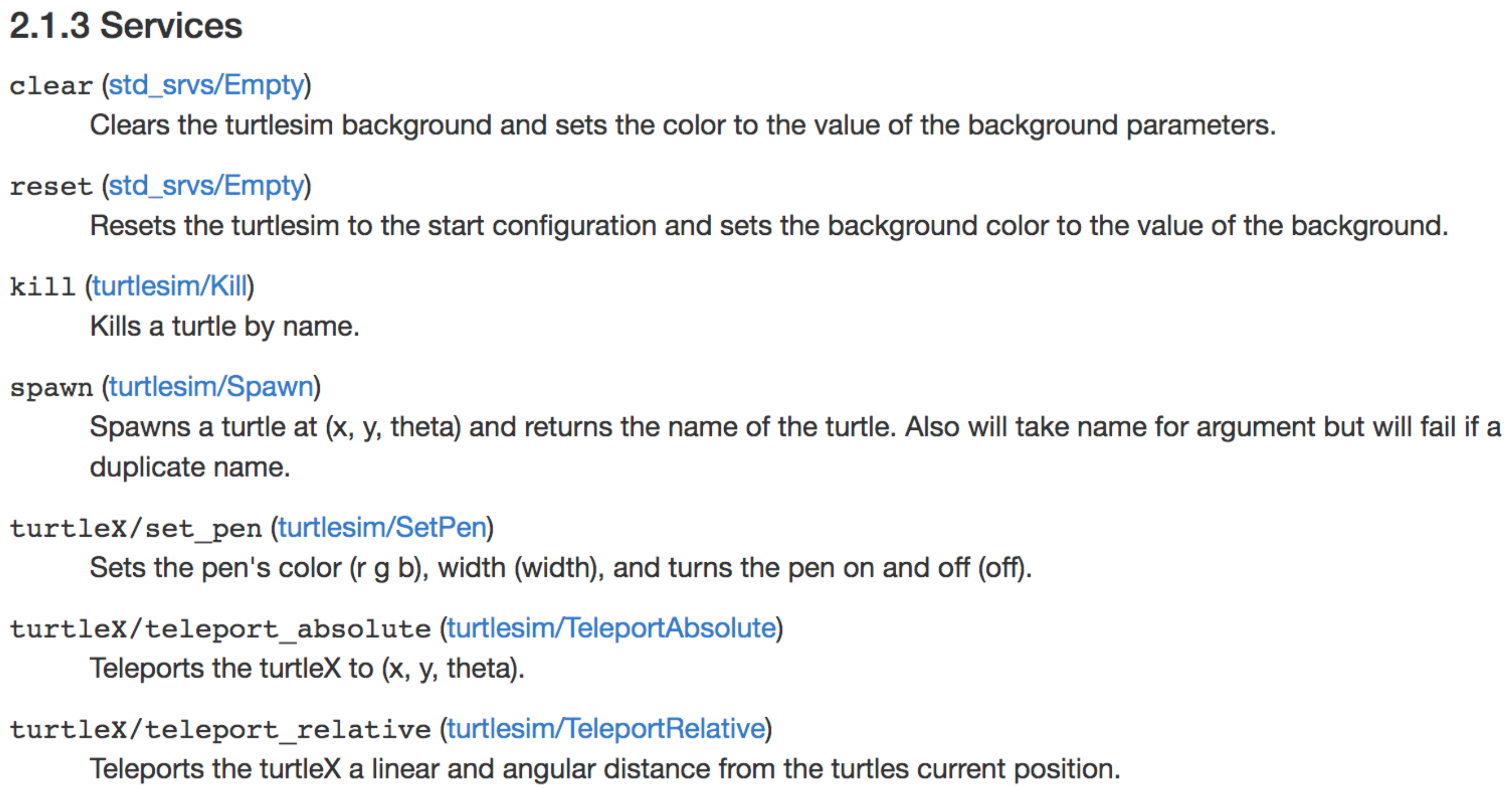
If everything works correctly, you should see messages in the fourth terminal detailing the pose of the turtle



```
[ INFO] [1579360943.664355158]: position=(3.92,5.76) direction=0.87
[ INFO] [1579360943.680300126]: position=(3.94,5.77) direction=0.88
[ INFO] [1579360943.695999972]: position=(3.95,5.79) direction=0.90
[ INFO] [1579360943.712432184]: position=(3.97,5.81) direction=0.91
[ INFO] [1579360943.727963946]: position=(3.98,5.83) direction=0.93
[ INFO] [1579360943.744337128]: position=(4.00,5.85) direction=0.94
[ INFO] [1579360943.759466689]: position=(4.01,5.87) direction=0.95
[ INFO] [1579360943.776494199]: position=(4.02,5.89) direction=0.97
[ INFO] [1579360943.791662779]: position=(4.04,5.91) direction=0.98
[ INFO] [1579360943.808297093]: position=(4.05,5.93) direction=1.00
[ INFO] [1579360943.823777829]: position=(4.06,5.95) direction=1.01
[ INFO] [1579360943.839688780]: position=(4.08,5.98) direction=1.02
[ INFO] [1579360943.855985925]: position=(4.09,6.00) direction=1.04
[ INFO] [1579360943.872017937]: position=(4.10,6.02) direction=1.05
[ INFO] [1579360943.888096973]: position=(4.11,6.04) direction=1.06
[ INFO] [1579360943.903398620]: position=(4.12,6.06) direction=1.08
[ INFO] [1579360943.920691261]: position=(4.13,6.08) direction=1.09
```

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`

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");
```

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

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");
```

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

```
/* 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");
```

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
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 call the service with the associated arguments

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
```

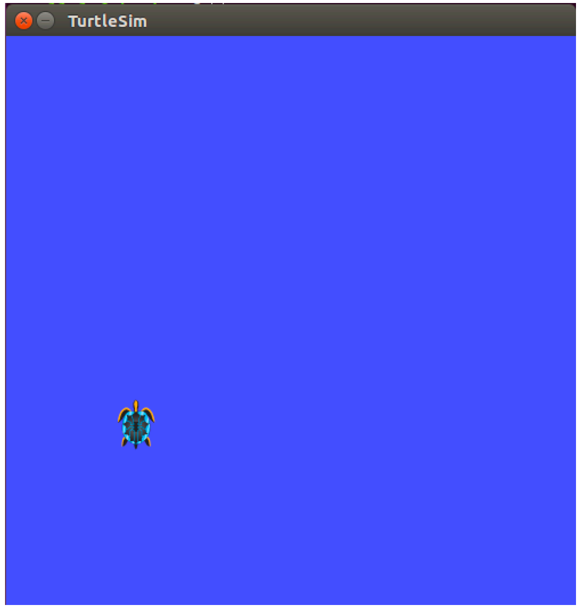
Open a third terminal and enter

```
~$ rosrun agitr useservices
```

Example Client Program to Use Services

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

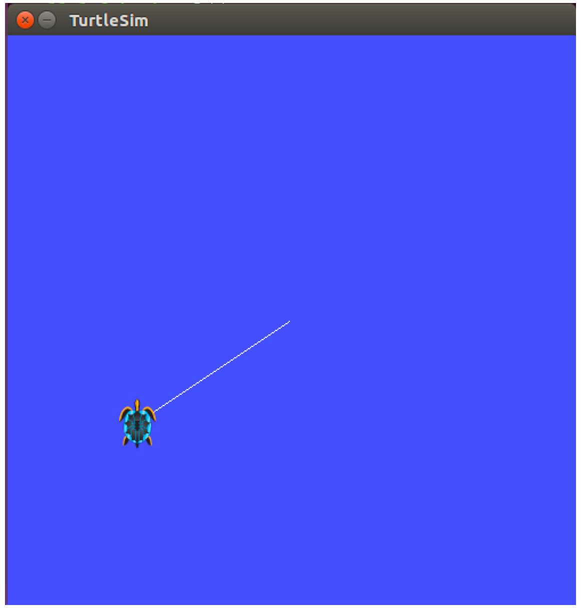
If everything works correctly, you should see the following



Example Client Program to Use Services

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

If you comment out the first call to the set_pen service to turn the pen off, run catkin_make, and run the program again, you should see the following



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/`