上海科技大学
ShanghaiTech University

ROS BASICS

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https://robotics.shanghaitech.edu.cn

With lots of material from last years summer school by
Ling Chen lcheno@shu.edu.cn (Shanghai University)
and with material by Levi Armstrong and Jonathan Meyer SwRI
"ROS-Industrial Basic Developer's Training Class 2016"

Outline

- Reviews
- Learning by Practice:
- How to customize your own message and service
- How to publish a topic
- How to subscribe a topic
- How to build a service server
- How to build a client
- Actions
- Roslaunch

Robot Software: Tasks/ Modules/ Programs (ROS: node)

Support

- Communication with Micro controller
- Sensor drivers
- Networking
  - With other PCs, other Robots, Operators
- Data storage
  - Store all data for offline processing and simulation and testing
- Monitoring/ Watchdog

Robotics

- Control
- Navigation
- Planning
- Sensor data processing
  - e.g. Stereo processing, Image rectification
- Mapping
- Localization
- Object Recognition
- Mission Execution
- Task specific computing, e.g.:
  - View planning, Victim search, Planning for robot arm, …

Software Design

- Modularization:
  - Keep different software components separated
  - ☺ Keep complexity low
  - ☺ Easily exchange a component (with a different, better algorithm)
  - ☺ Easily exchange multiple components with simulation
  - ☺ Easily exchange components with replay from hard disk instead of live sensor data
  - ☺ Multiple programming teams working on different components easier
  - Need: Clean definition of interfaces or exchange messages!
  - Allows: Multi-Process (vs. Single-Process, Multi-Thread) robot software system
  - Allows: Distributing computation over multiple computers

Review for ROS

- Different components, modules, algorithms run in different processes: **nodes**
- Nodes communicate using **messages** (and **services** …)
- Nodes **publish** and **subscribe** to **messages** by using names (**topics**)
- **Messages** are often passed around as shared pointers which are
  - “write protected” using the const keyword
  - The shared pointers take the message type as template argument
  - Shared pointers can be accessed like normal pointers

Constant Variables

- Declare variables that do not change (anymore) in the code: `const`
- Works for variables and objects
- Const Objects:
  - Only methods that do not change any variable of the object may be called =>
  - Those methods have to be declared const
- Used for program-correctness
- Especially for multi-threading:
  - Share the data (e.g. image)
  - Make it read only via const
  - => no side-effects between different threads

1. const int x = 5; // x may not be changed
2. int * someValue = &x; // pointer – compilation error!!
3. const int * pointy = &x; // good
4. *pointy = 8; // error – pointing to const!
5. int y = 4;
6. pointy = &y; // from non const to const is always possible!
7. const int * p2 const = &y; // pointing to const variable and p2 is also const
8. p2 = &x; // error – p2 is const

C++ Templates

- Functions and classes that operate with generic types
- Function or class works on many different data types without rewrite
  - `template <typename T> int compare( T v1, T v2);`
  - Type of T is determined during compile time => errors during compilation (and not run-time)
  - Any type (type == class) that offers the needed methods & variables can be used
  - Usage: `compare<string>( string(“string number one”), “hello world” );`
    - Explicit declaration: typename T = string
    - typename T can (most often) deducted by the compiler from the argument types
- Class template:

```
template <typename T> class myStuff{
    T v1, v2;
    myStuff(T var1, T var2){  v1 = var2; v2 = var2; }
};
```

Template example

```cpp
template <typename Type>
Type max(Type a, Type b) {
    return a > b ? a : b;
}
```

```cpp
#include <iostream>

int main(int, char**)
{
  // This will call max <int> (by argument deduction)
  std::cout << max(3, 7) << std::endl;
  // This will call max<double> (by argument deduction)
  std::cout << max(3.0, 7.0) << std::endl;
  // This type is ambiguous, so explicitly instantiate max<double>
  std::cout << max<double>(3, 7.0) << std::endl;
  return 0;
}
```

Shared Pointer

- C++ Standard Library (std): heavily templated part of C++ Standard (many parts used to be in boost library)
- Pointer: address of some data in the heap – in the virtual address space
- Space for data has to be allocated (reserved) with: `new`
- After usage of data it has to be destroyed to free the memory: `delete`
- Problem: Data (e.g.) image is shared among different modules/ components/ threads. Who is the last user – who has to delete the data?
  - Shared pointer: counts the number of users (smart pointers); upon destruction of last user (smart pointer) the object gets destroyed : called “Reference counting”
  - Problem: Shared pointer needs to know the destructor method for the pointer =>
  - Shared pointer is a templated class: Template argument: class type of the object pointed to
  - Shared pointer can also point to const object!

Shared pointer example

```
std::shared_ptr<int> p1(new int(5));
std::shared_ptr<int> p2 = p1; //Both now own the memory.

p1.reset(); //Memory still exists, due to p2.
p2.reset(); //Deletes the memory, since no one else owns the memory.
```

- Earlier, shared_ptr used to be in boost
- Excerpt from ROS message of type “String” :

```
typedef boost::shared_ptr< ::std_msgs::String_<ContainerAllocator> > Ptr;
typedef boost::shared_ptr< ::std_msgs::String_<ContainerAllocator> const> ConstPtr;
```

- typedef: create another (shorter) name for a certain type
- Our type: a shared pointer that points to a (complicated) String object

```
void chatterCallback(const std_msgs::String::ConstPtr& msg)
{
  ROS_INFO("I heard: [%s]", msg->data.c_str());
}
```

Messages

- Publisher does not know about subscribers
- Subscribers do not know publishers
- One topic name: many subscribers and many publishers possible, BUT: same message type (determined by the first publisher)!
- List all topics in the current system:
  - rostopic list
  - Other commands: `rostopic echo`, `rostopic hz`, `rostopic pub` , `rostopic pub /test std_msgs/String “Hello World!"`

Learning by Practice

- **How to customize your own message and service**
- How to publish a topic
- How to subscribe a topic
- How to build a service server
- How to build a client

Creating your own package

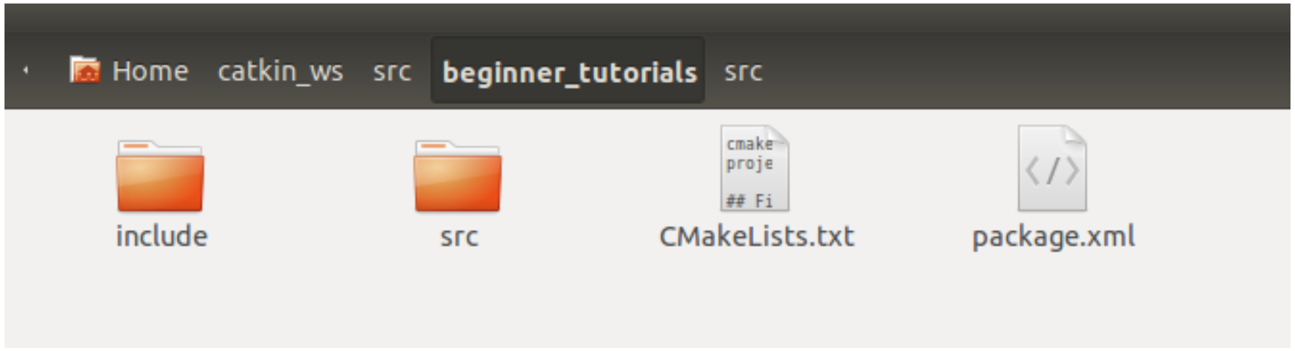
Creating your own package

- Create a new package

Creating your own package

- Create a new package

```
cd ~/catkin_ws/src
catkin_create_pkg beginner_tutorials std_msgs rospy roscpp
```



Creating your own package

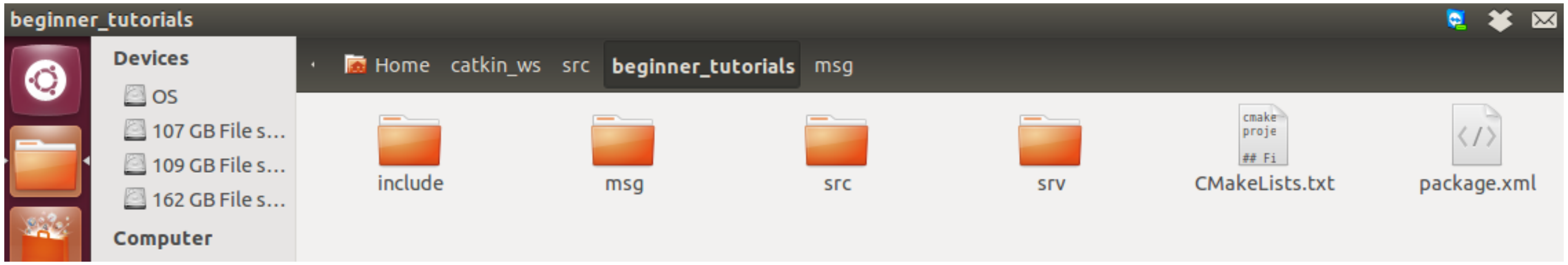
Creating your own package

- Make two folders for messages and services

Creating your own package

- Make two folders for messages and services

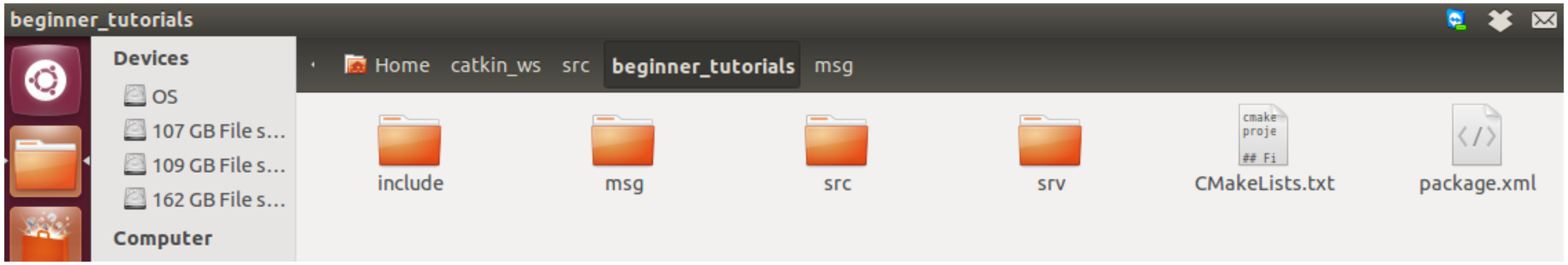
```
$ roscd beginner_tutorials
$ mkdir msg
$ mkdir srv
```



Creating your own package

- Make two folders for messages and services

```
$ roscd beginner_tutorials
$ mkdir msg
$ mkdir srv
```



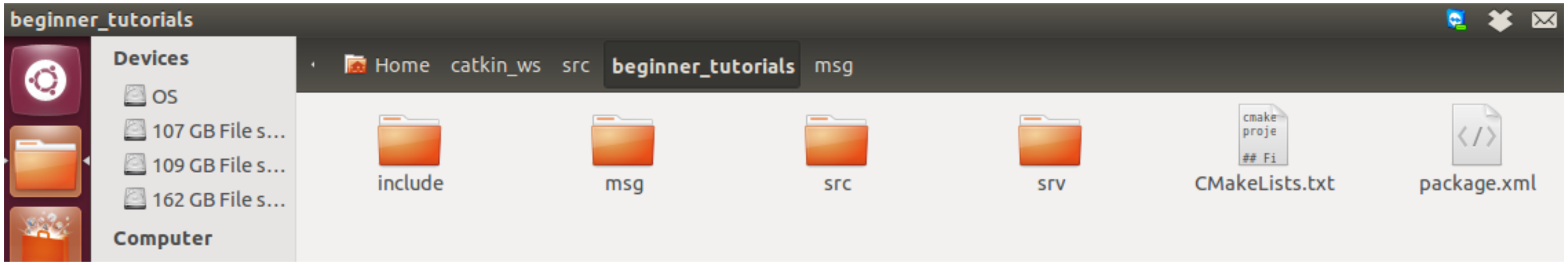
- In msg, create a file called AandB.msg, with content:

```
float32 a
float32 b
```

Creating your own package

- Make two folders for messages and services

```
$ roscd beginner_tutorials
$ mkdir msg
$ mkdir srv
```



- In msg, create a file called AandB.msg, with content:

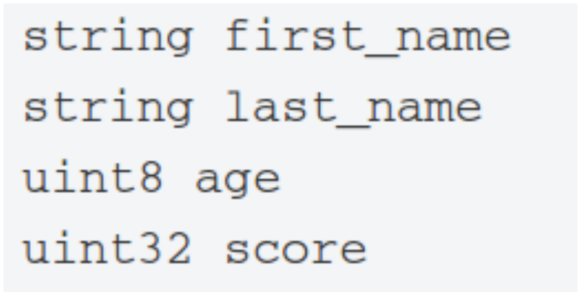
```
float32 a
float32 b
```

- In srv, create a file called AddTwoInts.srv, with content:

```
int64 a
int64 b
---
int64 sum
```

Create own message: Text format

- Types:
  - int8, int16, int32, int64 (plus uint*)
  - float32, float64
  - string
  - time, duration
  - other msg files
  - variable-length array[] and fixed-length array[C]



```
string first_name
string last_name
uint8 age
uint32 score
```

- Save in folder “msg”, start with big letter, end with “.msg”

Create own Services

- ROS **service**: send a "message" or command to service provider, wait for reply
- Text format: First message for **request**
  - Separation: three dashes
  - Then message for **response**
- A call to a service blocks
- Either or both data blocks may be empty!
- The response always includes a boolean to indicate success!

```
float32 x
float32 y
float32 theta
string name
---
string name
```

Modify Package.xml and CMakeLists.txt

Modify Package.xml and CMakeLists.txt

- **Change package.xml.**

Open package.xml, and make sure these two lines are in it and uncommented:

```
<build_depend>message_generation</build_depend>
<run_depend>message_runtime</run_depend>
```

Modify Package.xml and CMakeLists.txt

- **Change package.xml.**

Open package.xml, and make sure these two lines are in it and uncommented:

```
<build_depend>message_generation</build_depend>
<run_depend>message_runtime</run_depend>
```

- **Add message_generation dependency in CMakeLists.txt.**

```
find_package(catkin REQUIRED COMPONENTS    roscpp      rospy

std_msgs   message_generation)
```

Modify Package.xml and CMakeLists.txt

- **Change package.xml.**

Open package.xml, and make sure these two lines are in it and uncommented:

```
<build_depend>message_generation</build_depend>
<run_depend>message_runtime</run_depend>
```

- **Add message_generation dependency in CMakeLists.txt.**

```
find_package(catkin REQUIRED COMPONENTS   roscpp   rospy   std_msgs
message_generation)
```

- **Uncomment those lines:**

```
generate_messages(
  DEPENDENCIES
  std_msgs
)
```

- **Also make sure you export the message runtime dependency.**

```
catkin_package(
    …
    CATKIN_DEPENDS message_runtime …)
```

Modify Package.xml and CMakeLists.txt

Modify Package.xml and CMakeLists.txt

- **Change CMakelists.txt.**

Find the following block of code:

```
# add_message_files(
#   FILES
#   Message1.msg
#   Message2.msg
# )
```

Uncomment it by removing the # symbols and change to this: add_message_files(FILES AandB.msg)

Modify Package.xml and CMakeLists.txt

Change CMakelists.txt.

Find the following block of code:

```
# add_message_files(
#   FILES
#   Message1.msg
#   Message2.msg
# )
```

Uncomment it by removing the # symbols and change to this: add_message_files(FILES AandB.msg)

Remove # to uncomment the following lines:

```
# add_service_files(
#   FILES
#   Service1.srv
#   Service2.srv
# )
```

And replace the placeholder Service*.srv files for your service files:

add_service_files(FILES AddTwoInts.srv)

Modify Package.xml and CMakeLists.txt

- **package.xml should look like:**

```
<?xml version="1.0"?>
<package>
  <name>beginner_tutorials</name>
  <version>0.0.0</version>
  <description>The beginner_tutorials package</description>
  <maintainer email="ling@todo.todo">ling</maintainer>
  <license>TODO</license>

  <build_depend>message_generation</build_depend>
  <buildtool_depend>catkin</buildtool_depend>
  <run_depend>message_runtime</run_depend>

  <buildtool_depend>catkin</buildtool_depend>
  <build_depend>roscpp</build_depend>
  <build_depend>rospy</build_depend>
  <build_depend>std_msgs</build_depend>
  <run_depend>roscpp</run_depend>
  <run_depend>rospy</run_depend>
  <run_depend>std_msgs</run_depend>

  <export>
  </export>
</package>
```

Modify Package.xml and CMakeLists.txt

- **CMakeLists.txt could look like:** http://robotics.shanghaitech.edu.cn/static/ROS/

```
cmake_minimum_required(VERSION 2.8.3)
project(beginner_tutorials)
find_package(catkin REQUIRED COMPONENTS
  roscpp
  rospy
  std_msgs
  message_generation
)
add_message_files(   FILES   AandB.msg  )
add_service_files (  FILES    AddTwoInts.srv  )
generate_messages(   DEPENDENCIES    std_msgs  )
catkin_package(   CATKIN_DEPENDS roscpp rospy std_msgs
message_runtime )
include_directories(   ${catkin_INCLUDE_DIRS} )
```

Learning by Practice

- How to customize your own message and service
- **How to publish a topic**
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ROS C++ Client Library

- **roscpp** is a ROS client implementation in C++

- Library documentation can be found at:
  - http://docs.ros.org/api/roscpp/html/

- ROS header files can be found at: /opt/ros/hydro/include
  - For example, /opt/ros/hydro/include/ros/ros.h

- ROS core binaries are located at: /opt/ros/hydro/bin
  - For example, /opt/ros/hydro/bin/rosrun

ROS Init

- A version of ros::init() must be called before using any of the rest of the ROS system

- Typical call in the main() function:

```
ros::init(argc, argv, “Node name”);
```

- Node names must be unique in a running system

ros::NodeHandle

- The main access point to communications with the ROS system.
  - Provides public interface to topics, services, parameters, etc.

- Create a handle to this process’ node (after the call to ros::init()) by declaring:

```
ros::NodeHandle n;
```

  - The first NodeHandle constructed will fully initialize the current node
  - The last NodeHandle destructed will close down the node

ros::Publisher

- Manages an advertisement on a specific topic.
- A Publisher is created by calling **NodeHandle::advertise()**
  - Registers this topic in the master node
- Example for creating a publisher:

```
ros::Publisher chatter_pub = n.advertise<std_msgs::String>("chatter", 1000);
```

  - First parameter is the topic name
  - Second parameter is the queue size
- Once all Publishers for a given topic go out of scope the topic will be unadvertised

ros::Rate

- A class to help run loops at a desired frequency.
- Specify in the constructor the desired rate to run in Hz

```
ros::Rate loop_rate(10);
```

- ros::Rate::sleep() method
  - Sleeps for any leftover time in a cycle.
  - Calculated from the last time sleep, reset, or the constructor was called

ros::ok()

- Call **ros::ok()** to check if the node should continue running

- ros::ok() will return false if:
  - a SIGINT is received (Ctrl-C)
  - we have been kicked off the network by another node with the same name
  - ros::shutdown() has been called by another part of the application.
  - all ros::NodeHandles have been destroyed

talker.cpp C++ Publisher Node Example

http://robotics.shanghaitech.edu.cn/static/ROS/

```
#include "ros/ros.h"
#include "beginner_tutorials/AandB.h"

int main(int argc, char **argv)
{
    ros::init(argc, argv, "talker"); // Initiate new ROS node named "talker"

    ros::NodeHandle n;
    ros::Publisher chatter_pub = n.advertise<beginner_tutorials::AandB>("chatter", 1000);
    ros::Rate loop_rate(10);

    int count = 0;
    while (ros::ok()) // Keep spinning loop until user presses Ctrl+C
    {
        beginner_tutorials::AandB msg;
        msg.a = 1.0;
        msg.b = 2.0;

        ROS_INFO("msg a: %.6f, msg b:%.6f", msg.a, msg.b);

        chatter_pub.publish(msg);

        ros::spinOnce(); // Need to call this function often to allow ROS to process incoming messages

        loop_rate.sleep(); // Sleep for the rest of the cycle, to enforce the loop rate
        count++;
    }
    return 0;
}
```

CMakeLists.txt

```
cmake_minimum_required(VERSION 2.8.3)
project(beginner_tutorials)
find_package(catkin REQUIRED COMPONENTS
  roscpp
  rospy
  std_msgs
  message_generation
)
add_message_files(   FILES   AandB.msg  )
add_service_files (  FILES    AddTwoInts.srv  )
generate_messages(   DEPENDENCIES     std_msgs   )
catkin_package(   CATKIN_DEPENDS roscpp rospy std_msgs
message_runtime )
include_directories(   ${catkin_INCLUDE_DIRS} )
add_executable(talker src/talker.cpp)
target_link_libraries(talker ${catkin_LIBRARIES})
add_dependencies(talker beginner_tutorials_generate_messages_cpp)
```

CMakeLists.txt

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cmake_minimum_required(VERSION 2.8.3)
project(beginner_tutorials)
find_package(catkin REQUIRED COMPONENTS
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target_link_libraries(talker ${catkin_LIBRARIES})
add_dependencies(talker beginner_tutorials_generate_messages_cpp)
```

Add the red parts
To CMakeLists.txt

Building Your Nodes

- Note the bottom line in the CMakeLists file:

```
add_dependencies(talker beginner_tutorials_generate_message_cpp)
```

  - This makes sure message headers are generated before being used
- After changing the CMakeLists file call catkin_make

```
$ cd ~/catkin_ws
$ catkin_make
```

Running the Node From Terminal

- Make sure you have sourced your workspace's setup.sh file after calling catkin_make:

```
$ cd ~/catkin_ws
$ source ./devel/setup.bash
```

  - Can add this line to your .bashrc startup file
- Now you can use rosrun to run your node:

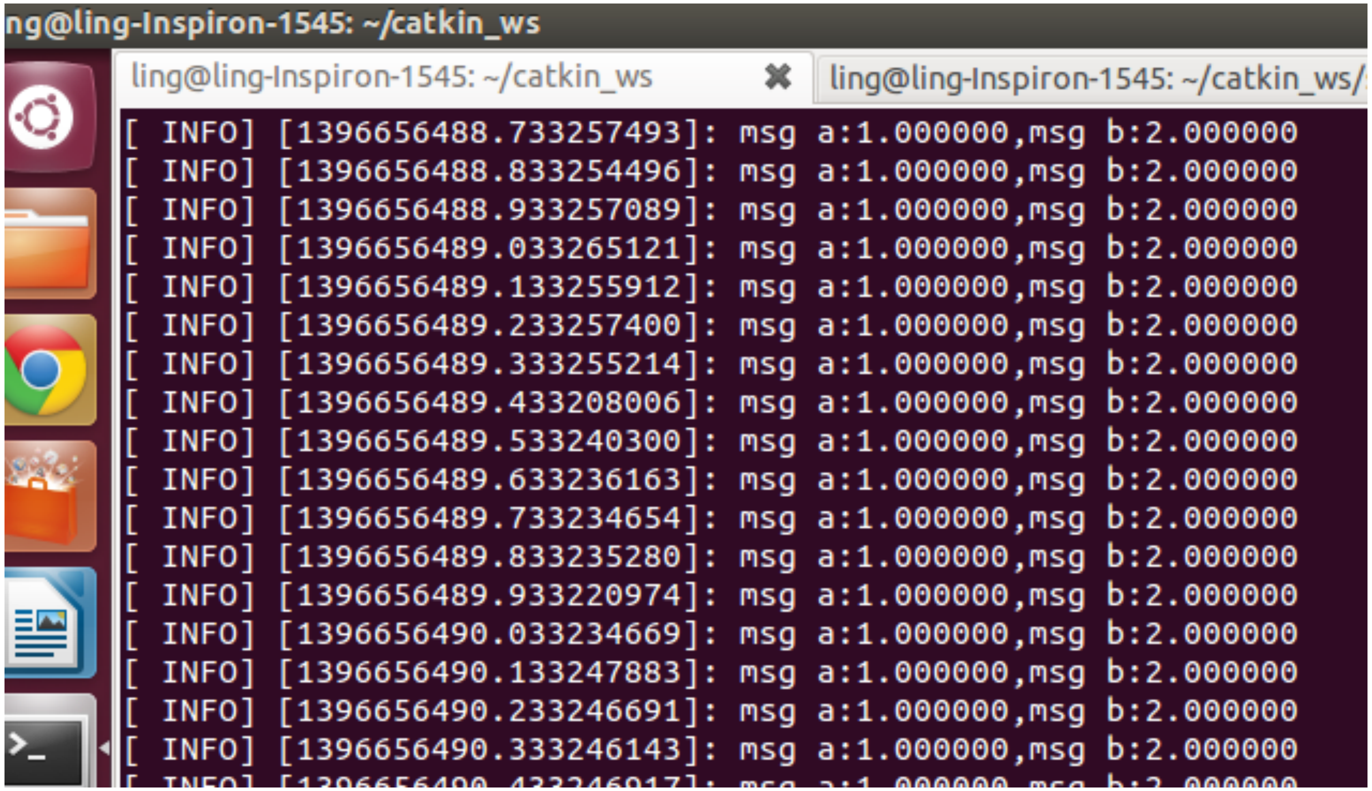
```
$ rosrun beginner_tutorials talker
```

Debugging the Node

```
$ cd ~/catkin_ws/build
$ cmake ../src -DCMAKE_BUILD_TYPE=Debug
```

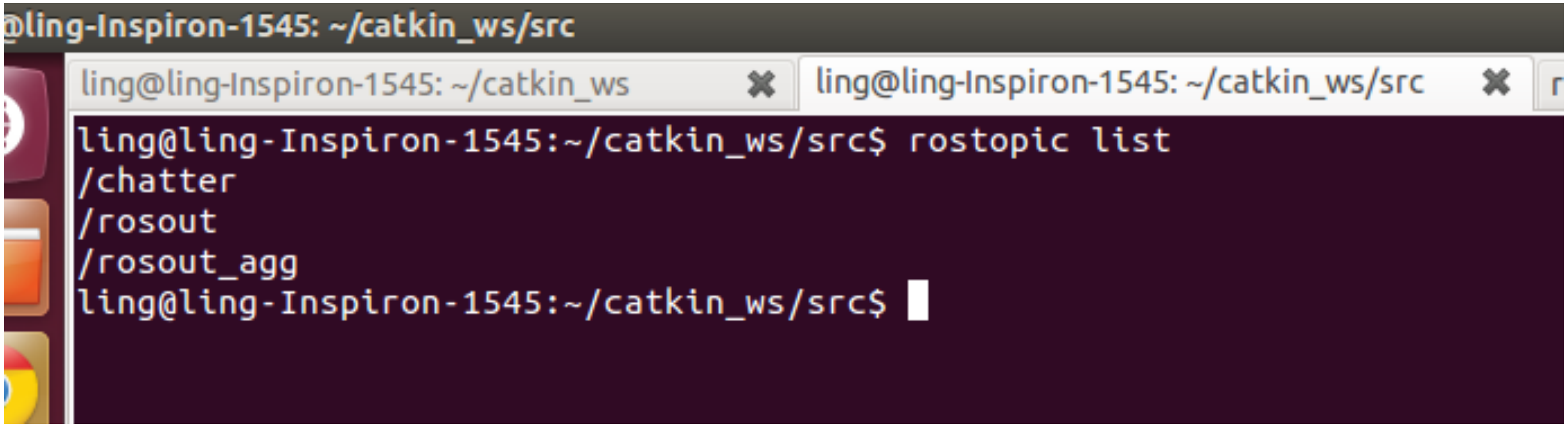
- Tell cmake to create debug symbols
- Find the executable in the devel folder: ~/catkin_ws/devel/lib/beginner_tutorials/talker
- cd ~/catkin_ws/devel/lib/beginner_tutorials
- Debug using gdb:
- gdb ./talker

Running the Node From Terminal


```
ng@ling-Inspiron-1545: ~/catkin_ws
ling@ling-Inspiron-1545: ~/catkin_ws    ling@ling-Inspiron-1545: ~/catkin_ws/
[ INFO] [1396656488.733257493]: msg a:1.000000,msg b:2.000000
[ INFO] [1396656488.833254496]: msg a:1.000000,msg b:2.000000
[ INFO] [1396656488.933257089]: msg a:1.000000,msg b:2.000000
[ INFO] [1396656489.033265121]: msg a:1.000000,msg b:2.000000
[ INFO] [1396656489.133255912]: msg a:1.000000,msg b:2.000000
[ INFO] [1396656489.233257400]: msg a:1.000000,msg b:2.000000
[ INFO] [1396656489.333255214]: msg a:1.000000,msg b:2.000000
[ INFO] [1396656489.433208006]: msg a:1.000000,msg b:2.000000
[ INFO] [1396656489.533240300]: msg a:1.000000,msg b:2.000000
[ INFO] [1396656489.633236163]: msg a:1.000000,msg b:2.000000
[ INFO] [1396656489.733234654]: msg a:1.000000,msg b:2.000000
[ INFO] [1396656489.833235280]: msg a:1.000000,msg b:2.000000
[ INFO] [1396656489.933220974]: msg a:1.000000,msg b:2.000000
[ INFO] [1396656490.033234669]: msg a:1.000000,msg b:2.000000
[ INFO] [1396656490.133247883]: msg a:1.000000,msg b:2.000000
[ INFO] [1396656490.233246691]: msg a:1.000000,msg b:2.000000
[ INFO] [1396656490.333246143]: msg a:1.000000,msg b:2.000000
[ INFO] [1396656490.433246917]: msg a:1.000000,msg b:2.000000
```

Examine node talker

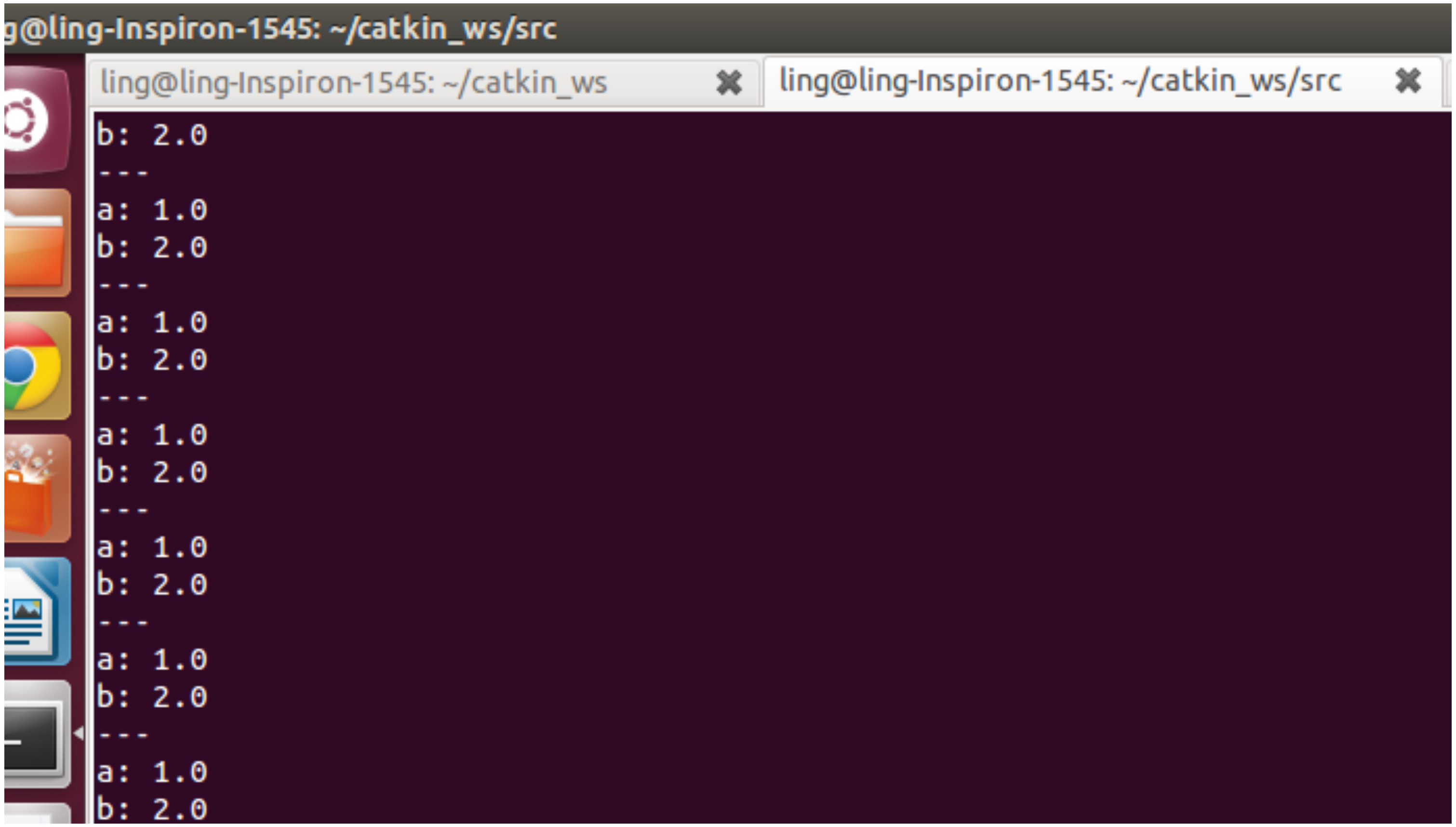
```
$ rostopic list
```


@ling-Inspiron-1545: ~/catkin_ws/src
ling@ling-Inspiron-1545: ~/catkin_ws
ling@ling-Inspiron-1545: ~/catkin_ws/src

```
ling@ling-Inspiron-1545:~/catkin_ws/src$ rostopic list
/chatter
/rosout
/rosout_agg
ling@ling-Inspiron-1545:~/catkin_ws/src$
```

Examine node talker

```
$ rostopic echo /chatter
```



g@ling-Inspiron-1545: ~/catkin_ws/src
ling@ling-Inspiron-1545: ~/catkin_ws
ling@ling-Inspiron-1545: ~/catkin_ws/src

```
b:  2.0
---
a:  1.0
b:  2.0
---
a:  1.0
b:  2.0
---
a:  1.0
b:  2.0
---
a:  1.0
b:  2.0
---
a:  1.0
b:  2.0
---
a:  1.0
b:  2.0
```

Learning by Practice

- How to customize your own message and service
- How to publish a topic
- **How to subscribe a topic**
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- How to build a client

Create node listener http://robotics.shanghaitech.edu.cn/static/ROS/

- Add the new source file: listener.cpp, save it

```
#include "ros/ros.h"
#include "beginner_tutorials/AandB.h"

void chatterCallback(const beginner_tutorials::AandB::ConstPtr& msg)
{
  ROS_INFO("I heard: msg:a %f, msg:b %f", msg->a, msg->b);
}

int main(int argc, char **argv)
{
  ros::init(argc, argv, "listener");

  ros::NodeHandle n;

  ros::Subscriber sub = n.subscribe("chatter", 1000, chatterCallback);

  ros::spin();

  return 0;
}
```

CMakeLists.txt

- CMakeLists.txt should look like:

```
cmake_minimum_required(VERSION 2.8.3)
project(beginner_tutorials)
find_package(catkin REQUIRED COMPONENTS
  roscpp
  rospy
  std_msgs
  message_generation
)
add_message_files(   FILES   AandB.msg  )
add_service_files (  FILES    AddTwoInts.srv  )
generate_messages(   DEPENDENCIES    std_msgs  )
catkin_package(   CATKIN_DEPENDS roscpp rospy std_msgs
message_runtime )
include_directories(   ${catkin_INCLUDE_DIRS} )
add_executable(talker src/talker.cpp)
target_link_libraries(talker ${catkin_LIBRARIES})

add_executable(listener src/listener.cpp)
target_link_libraries(listener ${catkin_LIBRARIES})

add_dependencies(talker beginner_tutorials_generate_messages_cpp)
```

CMakeLists.txt

- CMakeLists.txt should look like:

```
cmake_minimum_required(VERSION 2.8.3)
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message_runtime )
include_directories(   ${catkin_INCLUDE_DIRS} )
add_executable(talker src/talker.cpp)
target_link_libraries(talker ${catkin_LIBRARIES})

add_executable(listener src/listener.cpp)
target_link_libraries(listener ${catkin_LIBRARIES})

add_dependencies(talker beginner_tutorials_generate_messages_cpp)
```

Add the red parts
To CMakeLists.txt

Building node

- After changing the CMakeLists file call catkin_make

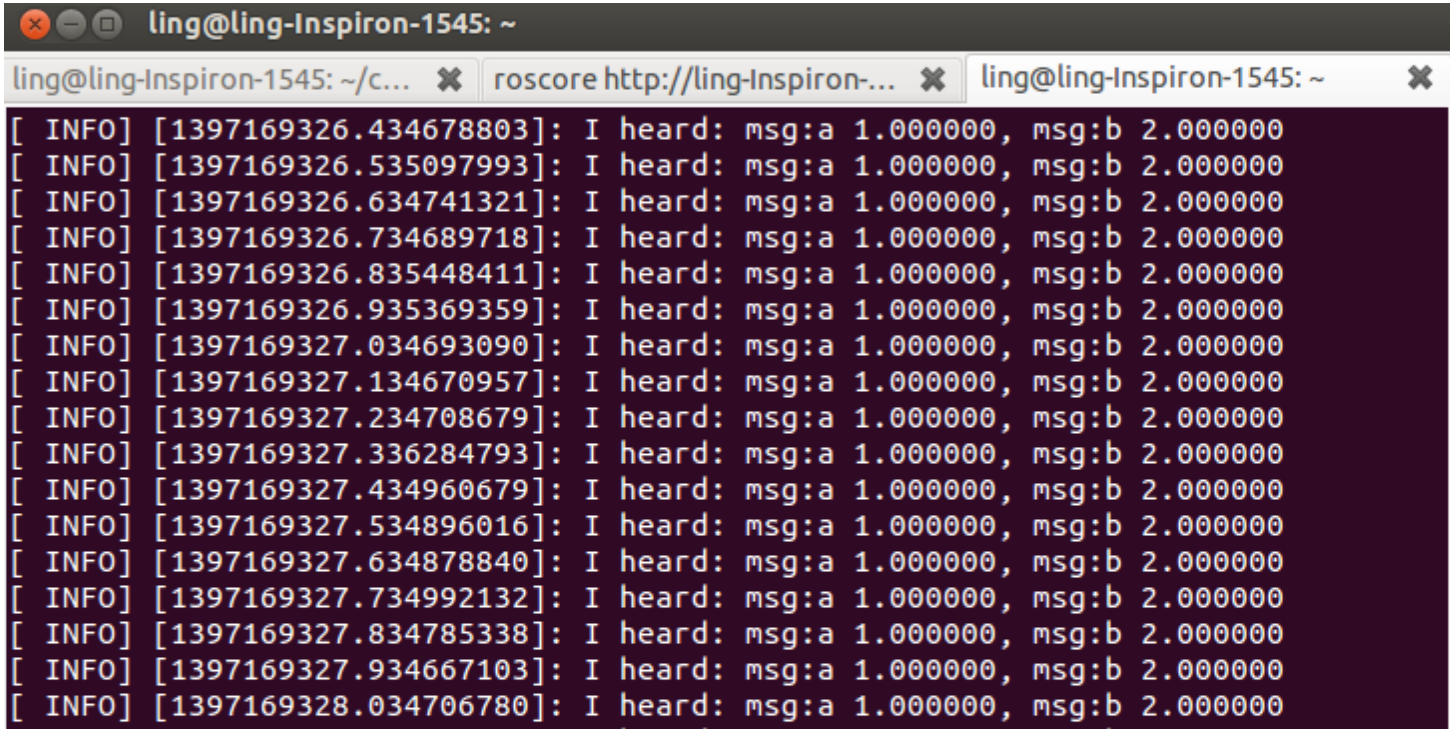
```
$ cd ~/catkin_ws
$ catkin_make
```

- Or in Eclipse, use short cut “Ctrl + B” to build all packages in the workspace.

Running node listener

- Open another terminal, short cut: Ctrl+Shift+T

```
$ rosrun beginner_tutorials listener
```


ling@ling-Inspiron-1545: ~
ling@ling-Inspiron-1545: ~/c...
roscore http://ling-Inspiron-...
ling@ling-Inspiron-1545: ~

```
[ INFO] [1397169326.434678803]: I heard: msg:a 1.000000, msg:b 2.000000
[ INFO] [1397169326.535097993]: I heard: msg:a 1.000000, msg:b 2.000000
[ INFO] [1397169326.634741321]: I heard: msg:a 1.000000, msg:b 2.000000
[ INFO] [1397169326.734689718]: I heard: msg:a 1.000000, msg:b 2.000000
[ INFO] [1397169326.835448411]: I heard: msg:a 1.000000, msg:b 2.000000
[ INFO] [1397169326.935369359]: I heard: msg:a 1.000000, msg:b 2.000000
[ INFO] [1397169327.034693090]: I heard: msg:a 1.000000, msg:b 2.000000
[ INFO] [1397169327.134670957]: I heard: msg:a 1.000000, msg:b 2.000000
[ INFO] [1397169327.234708679]: I heard: msg:a 1.000000, msg:b 2.000000
[ INFO] [1397169327.336284793]: I heard: msg:a 1.000000, msg:b 2.000000
[ INFO] [1397169327.434960679]: I heard: msg:a 1.000000, msg:b 2.000000
[ INFO] [1397169327.534896016]: I heard: msg:a 1.000000, msg:b 2.000000
[ INFO] [1397169327.634878840]: I heard: msg:a 1.000000, msg:b 2.000000
[ INFO] [1397169327.734992132]: I heard: msg:a 1.000000, msg:b 2.000000
[ INFO] [1397169327.834785338]: I heard: msg:a 1.000000, msg:b 2.000000
[ INFO] [1397169327.934667103]: I heard: msg:a 1.000000, msg:b 2.000000
[ INFO] [1397169328.034706780]: I heard: msg:a 1.000000, msg:b 2.000000
```

Learning by Practice

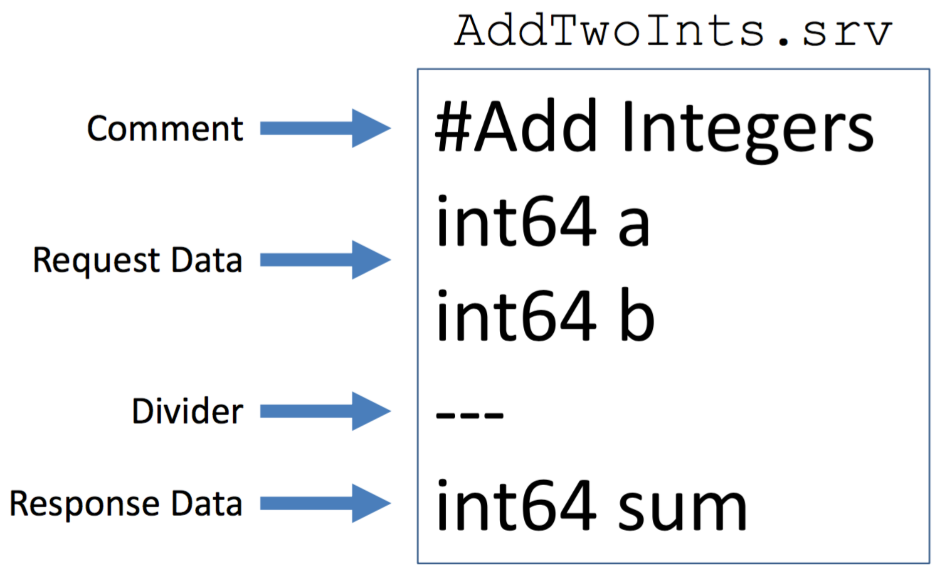
- How to customize your own message and service
- How to publish a topic
- How to subscribe a topic
- **How to implement a service server**
- How to build a client

Service

- Each Service is made up of 2 components:
  - Request : sent by client, received by server
  - Response : generated by server, sent to client
- Call to service blocks in client
  - Code will wait for service call to complete
  - Separate connection for each service call
- Typical Uses:
  - Algorithms: kinematics, perception
  - Closed-Loop Commands: move-to-position, open gripper

Service definition

- In srv/AddTwoInts.srv
- Catkin auto-generates C++ files for us…



```
#Add Integers
int64 a
int64 b
---
int64 sum
```

Create node add_two_ints_server

- Go to eclipse, new source file: add_two_ints_server.cpp

```
 #include "ros/ros.h"
#include "beginner_tutorials/AddTwoInts.h"

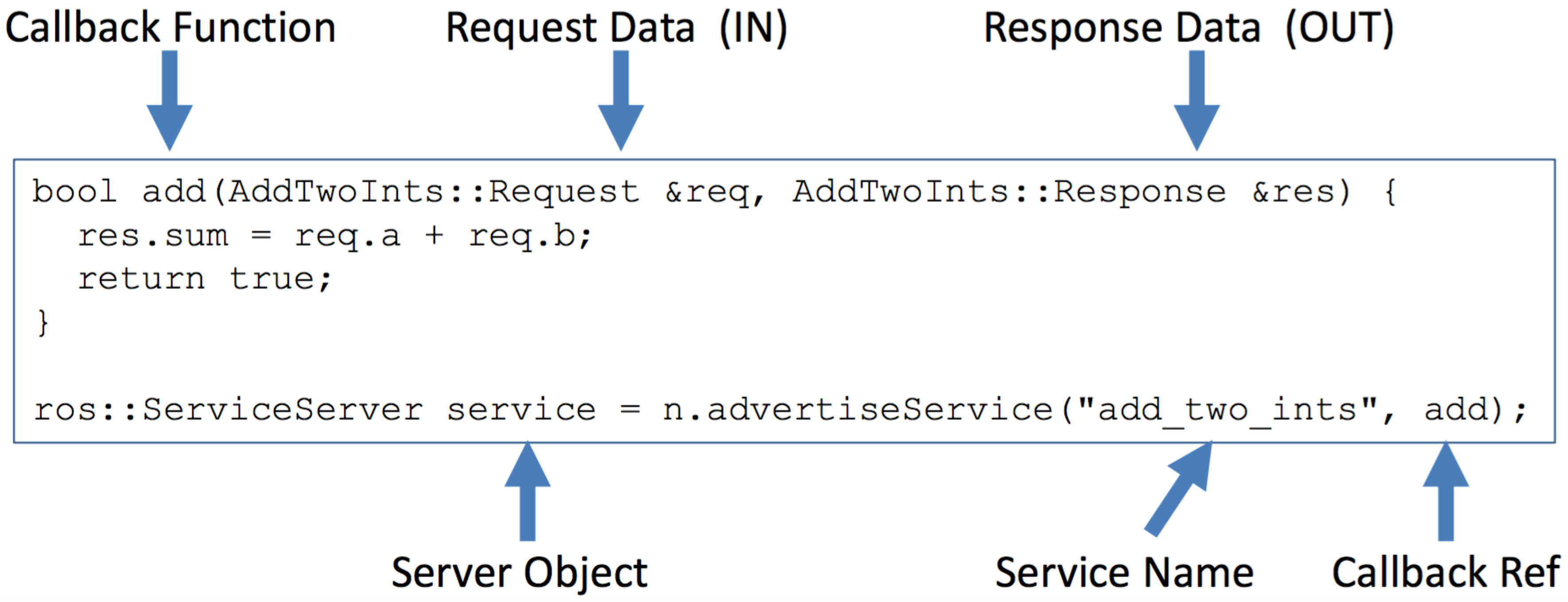
bool add(beginner_tutorials::AddTwoInts::Request  &req,
         beginner_tutorials::AddTwoInts::Response &res)
{
  res.sum = req.a + req.b;
  ROS_INFO("request: x=%ld, y=%ld", (long int)req.a, (long int)req.b);
  ROS_INFO("sending back response: [%ld]", (long int)res.sum);
  return true;
}
 int main(int argc, char **argv)
{  ros::init(argc, argv, "add_two_ints_server");
  ros::NodeHandle n;

  ros::ServiceServer service = n.advertiseService("add_two_ints", add);
  ROS_INFO("Ready to add two ints.");
  ros::spin();

  return 0;
}
```

http://robotics.shanghaitech.edu.cn/static/ROS/

- Service **Server**
  - Defines associated **Callback Function**
  - Advertises available service *(Name, Data Type)*



```
bool add(AddTwoInts::Request &req, AddTwoInts::Response &res) {
  res.sum = req.a + req.b;
  return true;
}

ros::ServiceServer service = n.advertiseService("add_two_ints", add);
```

CMakeLists.txt

- CMakeLists.txt should look like:

```
cmake_minimum_required(VERSION 2.8.3)
project(beginner_tutorials)
find_package(catkin REQUIRED COMPONENTS
  roscpp
  rospy
  std_msgs
  message_generation
)
add_message_files(   FILES   AandB.msg  )
add_service_files (  FILES    AddTwoInts.srv  )
generate_messages(   DEPENDENCIES    std_msgs  )
catkin_package(   CATKIN_DEPENDS roscpp rospy std_msgs message_runtime )
include_directories(   ${catkin_INCLUDE_DIRS} )
add_executable(talker src/talker.cpp)
target_link_libraries(talker ${catkin_LIBRARIES})
add_executable(listener src/listener.cpp)
target_link_libraries(listener ${catkin_LIBRARIES})

add_executable(add_two_ints_server  src/add_two_ints_server.cpp)
target_link_libraries(add_two_ints_server  ${catkin_LIBRARIES})

add_dependencies(talker beginner_tutorials_generate_messages_cpp)
```

CMakeLists.txt

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add_dependencies(talker beginner_tutorials_generate_messages_cpp)
```

Add the red parts
To CMakeLists.txt

Building node

- After changing the CMakeLists file call catkin_make

```
$ cd ~/catkin_ws
$ catkin_make
```

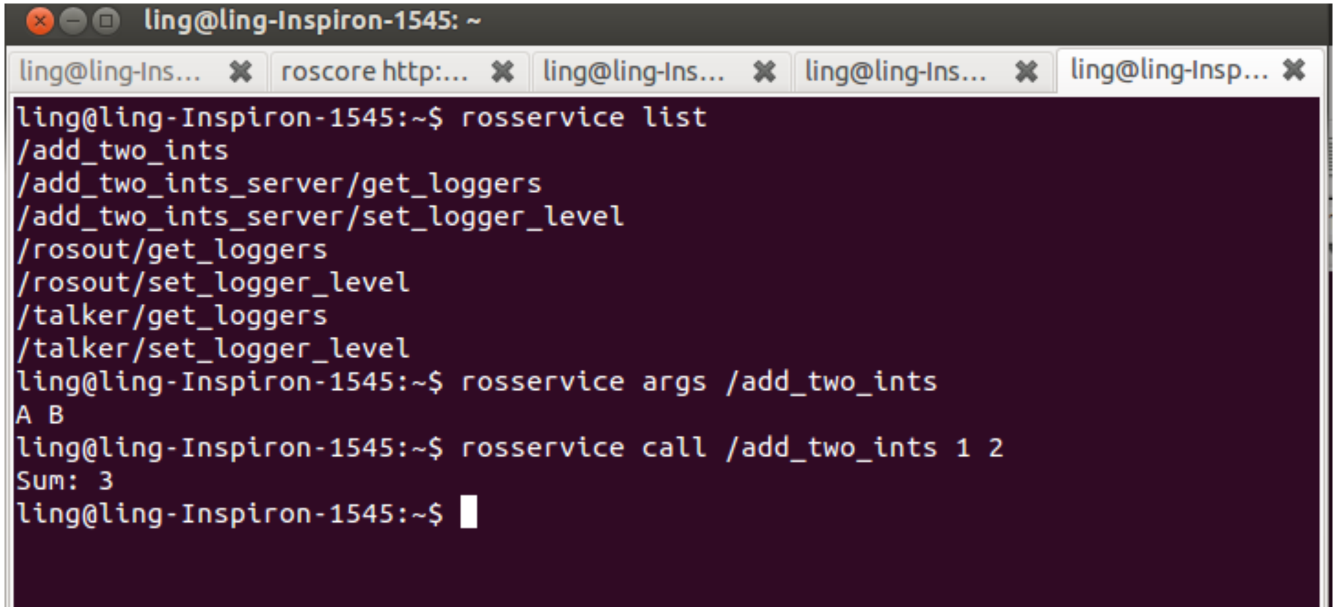
Running node add_two_ints_server

- Open another terminal, short cut: Ctrl+Shift+T

```
$ rosrun beginner_tutorials add_two_ints_server
```

- Open another terminal

```
$ rosservice list
$ rosservice args /add_two_ints
$ rosservice call /add_two_ints 1 2
```



```
ling@ling-Inspiron-1545:~$ rosservice list
/add_two_ints
/add_two_ints_server/get_loggers
/add_two_ints_server/set_logger_level
/rosout/get_loggers
/rosout/set_logger_level
/talker/get_loggers
/talker/set_logger_level
ling@ling-Inspiron-1545:~$ rosservice args /add_two_ints
A B
ling@ling-Inspiron-1545:~$ rosservice call /add_two_ints 1 2
Sum: 3
ling@ling-Inspiron-1545:~$
```

Learning by Practice

- How to customize your own message and service
- How to publish a topic
- How to subscribe a topic
- How to build a service server
- **How to build a client**

Create node add_two_ints_client

- Go to eclipse, new source file: add_two_ints_client.cpp

```
#include "ros/ros.h"
#include "beginner_tutorials/AddTwoInts.h"

int main(int argc, char **argv)
{
  ros::init(argc, argv, "add_two_ints_client");
  if (argc != 3)
  {
    ROS_INFO("usage: add_two_ints_client X Y");
    return 1;
  }
  ros::NodeHandle n;
  ros::ServiceClient client = n.serviceClient<beginner_tutorials::AddTwoInts>("add_two_ints");
  beginner_tutorials::AddTwoInts srv;
  srv.request.a = atoll(argv[1]);
  srv.request.b = atoll(argv[2]);
  if (client.call(srv))
  {
    ROS_INFO("Sum: %ld", (long int)srv.response.sum);
  }
  else
  {
    ROS_ERROR("Failed to call service add_two_ints");
    return 1;
  }
   return 0;
}
```

http://robotics.shanghaitech.edu.cn/static/ROS/

CMakeLists.txt

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add_executable(add_two_ints_client  src/add_two_ints_client.cpp)
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add_dependencies(talker beginner_tutorials_generate_messages_cpp)
```

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target_link_libraries(add_two_ints_server  ${catkin_LIBRARIES})

add_executable(add_two_ints_client  src/add_two_ints_client.cpp)
target_link_libraries(add_two_ints_client ${catkin_LIBRARIES})


add_dependencies(talker beginner_tutorials_generate_messages_cpp)
```

Add the red parts
To CMakeLists.txt

Building node

- After changing the CMakeLists file call catkin_make

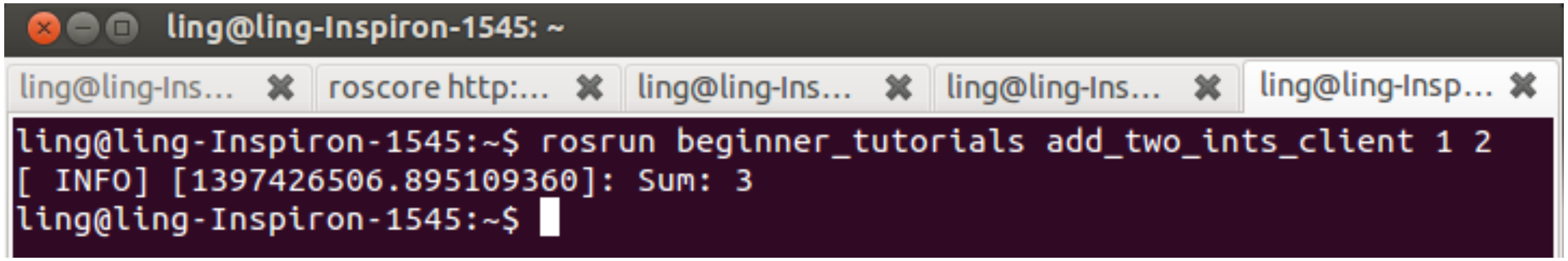
```
$ cd ~/catkin_ws
$ catkin_make
```

- Or in Eclipse, use short cut “Ctrl + B” to build all packages in the workspace.

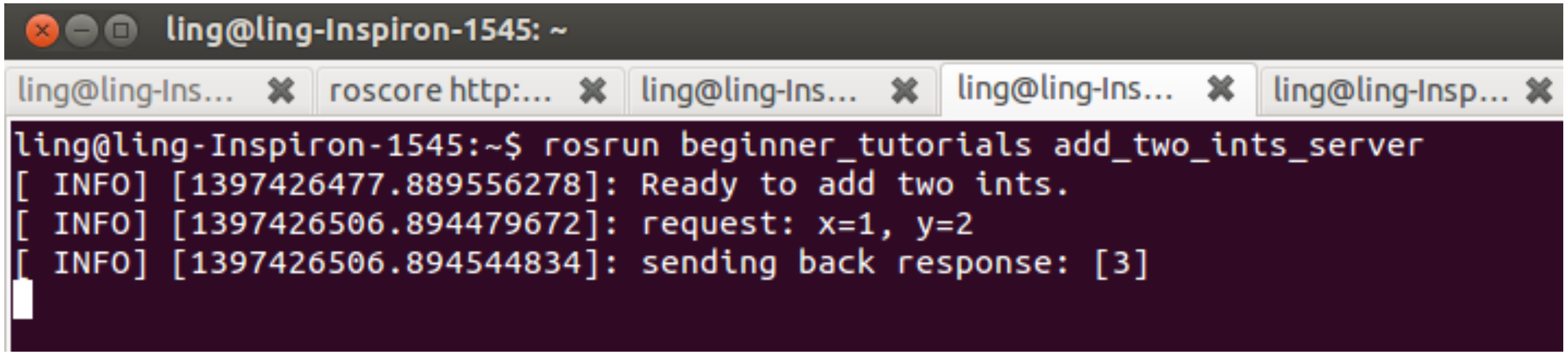
Running node add_two_ints_client

- Open another terminal, short cut: Ctrl+Shift+T

```
$ rosrun beginner_tutorials add_two_ints_client 1 2
```



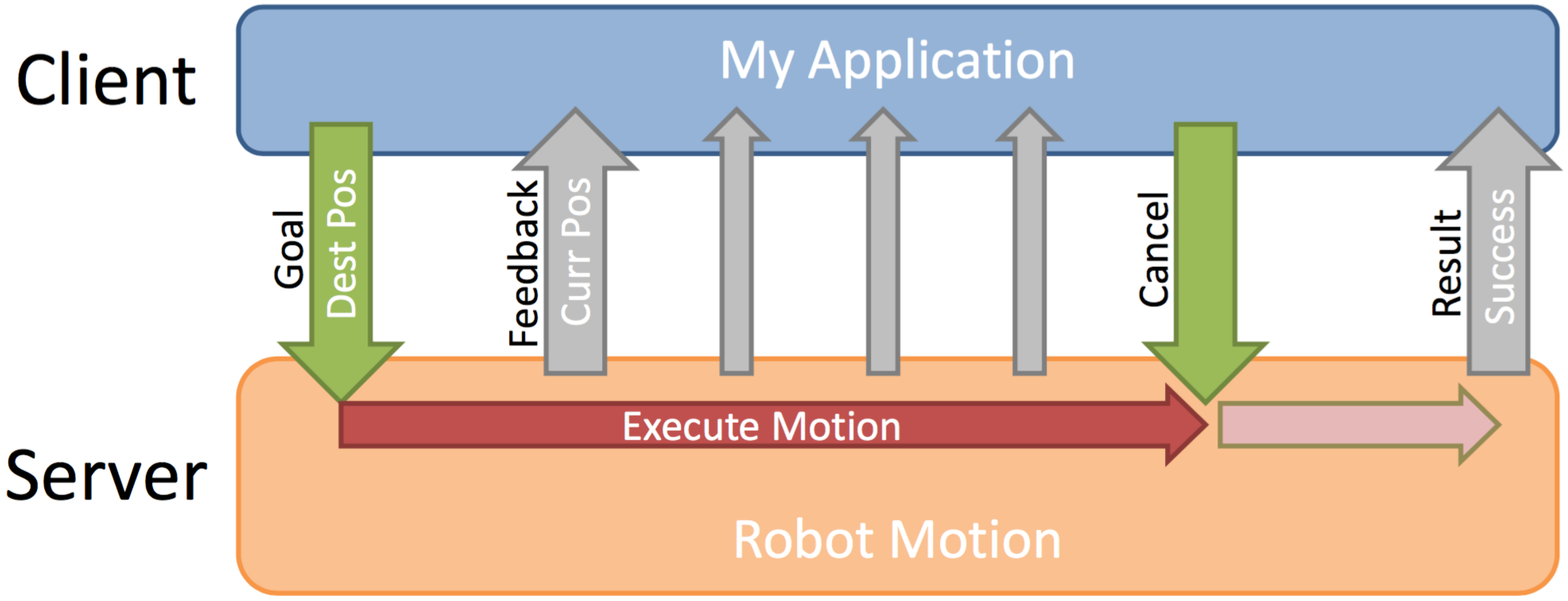
```
ling@ling-Inspiron-1545:~$ rosrun beginner_tutorials add_two_ints_client 1 2
[ INFO] [1397426506.895109360]: Sum: 3
ling@ling-Inspiron-1545:~$
```



```
ling@ling-Inspiron-1545:~$ rosrun beginner_tutorials add_two_ints_server
[ INFO] [1397426477.889556278]: Ready to add two ints.
[ INFO] [1397426506.894479672]: request: x=1, y=2
[ INFO] [1397426506.894544834]: sending back response: [3]
```

Advanced: Actions

Actions manage **Long-Running Tasks**

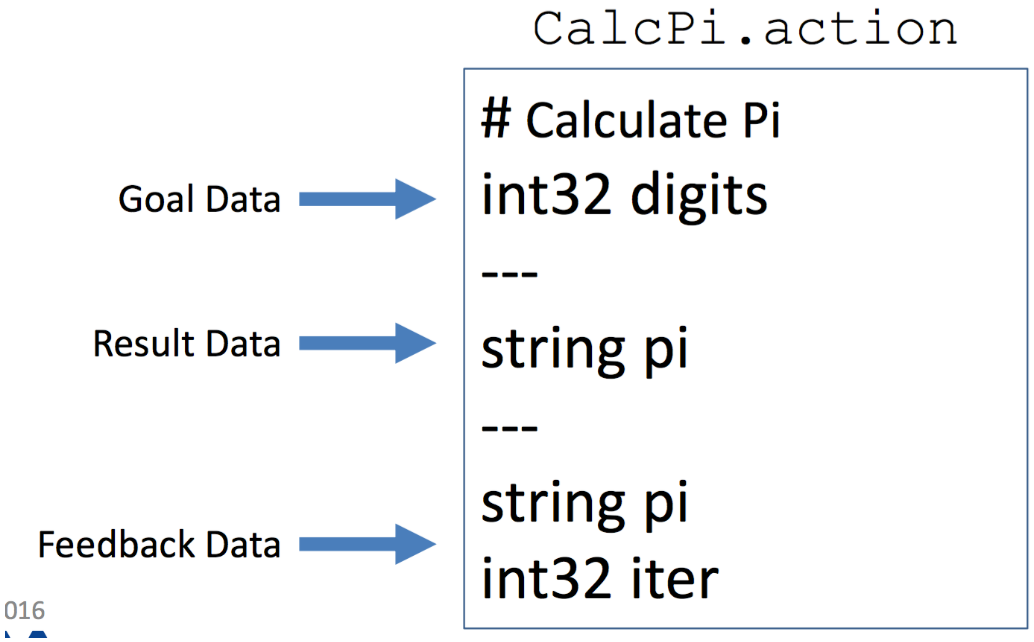


Actions: Details

- Each action is made up of 3 components:
  - Goal, sent by client, received by server
  - Result, generated by server, sent to client
  - Feedback, generated by server
- Non-blocking in client
  - Can monitor feedback or cancel before completion
- TypicalUses:
  - “Long” Tasks: Robot Motion, Path Planning
  - Complex Sequences: Pick Up Box, Sort Widgets

Action definition

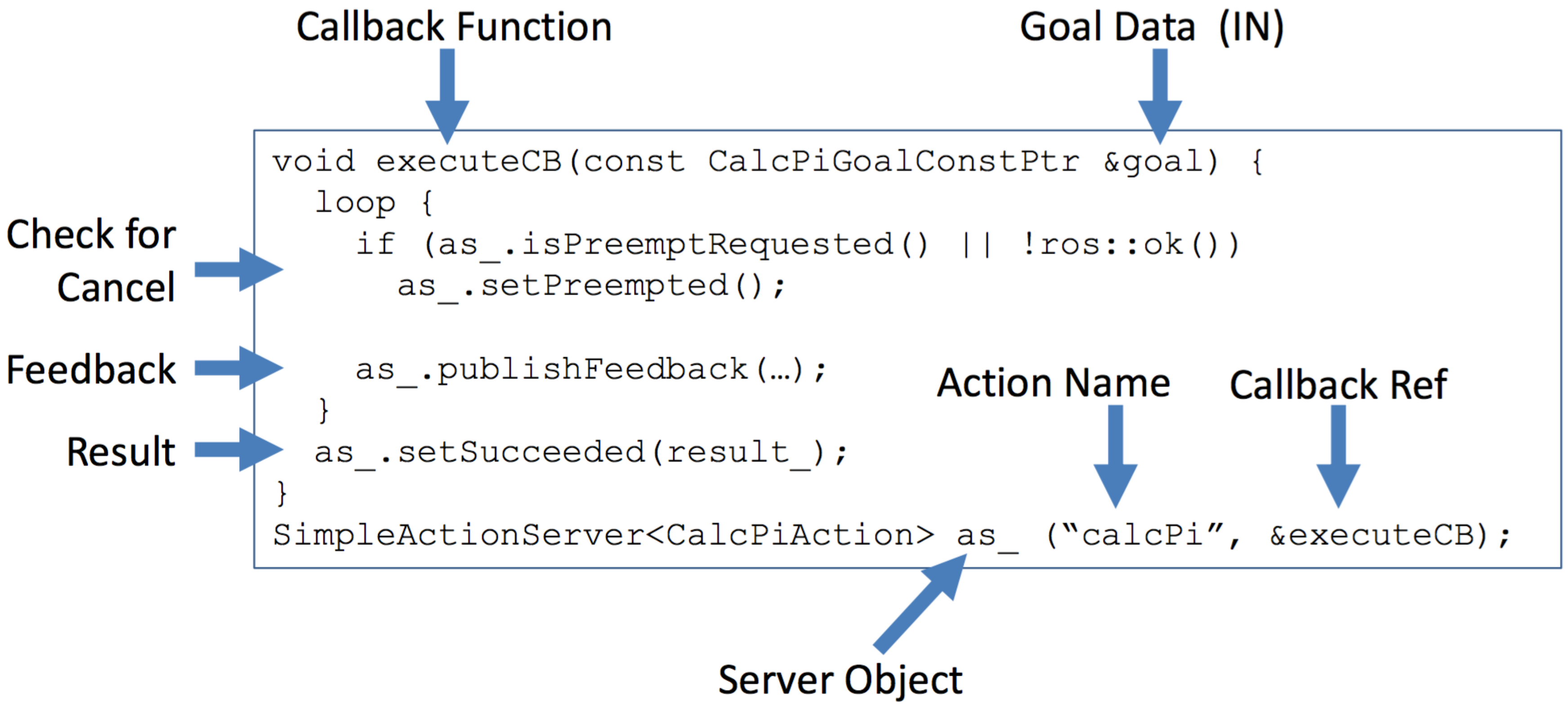
- Defines Goal, Feedback and Result data types
  - Any data block may be empty – they always receive handshakes
- Catkin auto-generates C++ files…



```
# Calculate Pi
int32 digits
---
string pi
---
string pi
int32 iter
```

Action Server

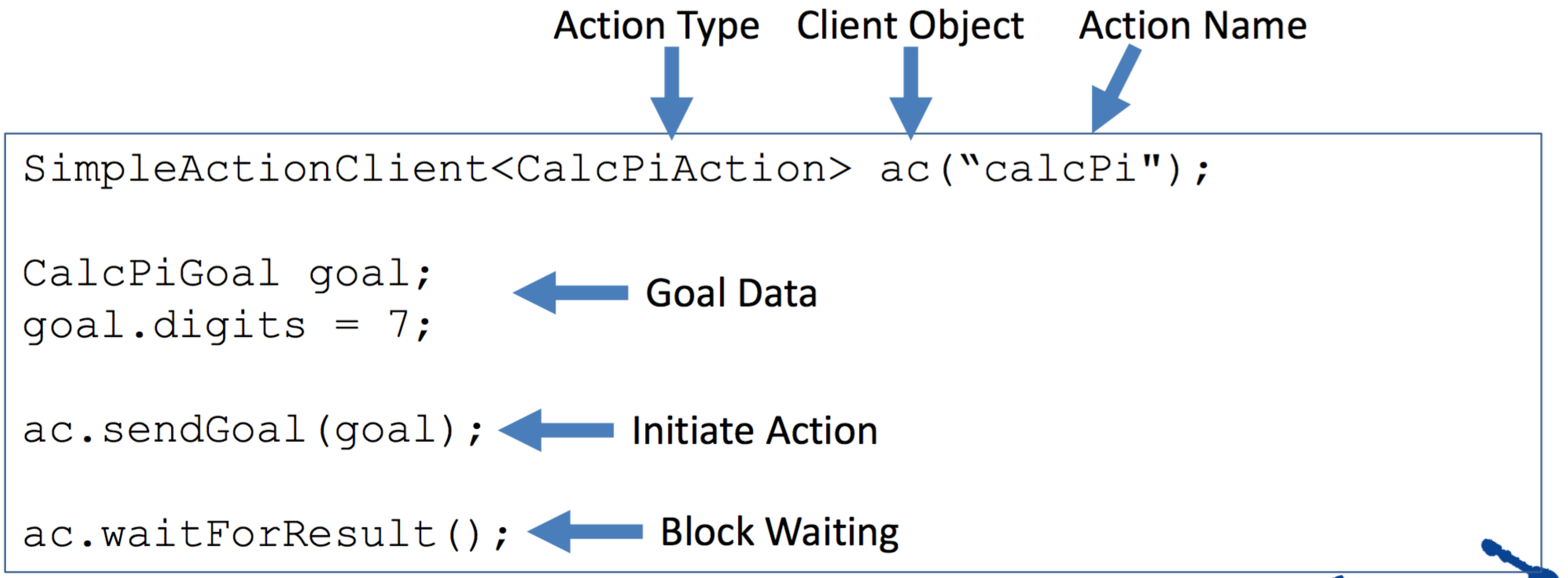
- Defines Execute Callback
- Periodically Publish Feedback
- Advertises available action (Name, Data Type)



```
void executeCB(const CalcPiGoalConstPtr &goal) {
  loop {
    if (as_.isPreemptRequested() || !ros::ok())
      as_.setPreempted();

    as_.publishFeedback(…);
  }
  as_.setSucceeded(result_);
}
SimpleActionServer<CalcPiAction> as_ ("calcPi", &executeCB);
```

Action Client

- Connects to specific Action (Name / Data Type)
- Fills in Goal data
- Initiate Action / Waits for Result



```
SimpleActionClient<CalcPiAction> ac(“calcPi");

CalcPiGoal goal;
goal.digits = 7;

ac.sendGoal(goal);

ac.waitForResult();
```

Message vs. Service vs. Action

Type	Strengths	Weaknesses
Message	•Good for most sensors (streaming data) •One - to - Many	•Messages can be <u>dropped</u> without knowledge •Easy to overload system with too many messages
Service	•Knowledge of missed call •Well-defined feedback	•Blocks until completion •Connection typically re-established for each service call (slows activity)
Action	•Monitor long-running processes •Handshaking (knowledge of missed connection)	•Complicated

roslaunch

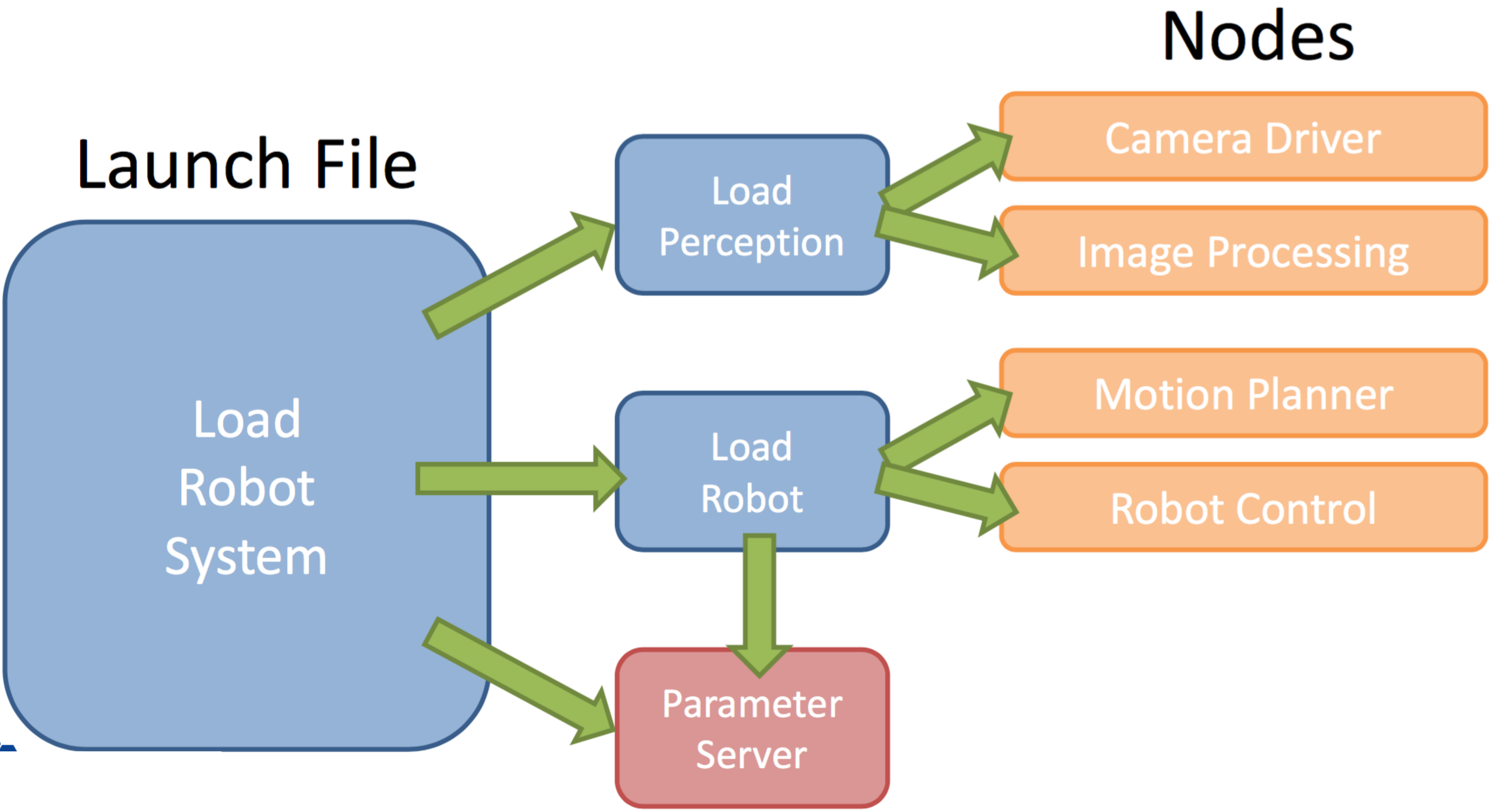
- ROS is a Distributed System
  - Often 10s of nodes plus configuration data
  - Painful to start each node manually

- roslaunch is a tool for easily launching multiple ROS nodes, and setting parameters on the Parameter Server.

- It takes in one or more XML configuration files (with the **.launch** extension) saved in the 'launch' folders in packages.

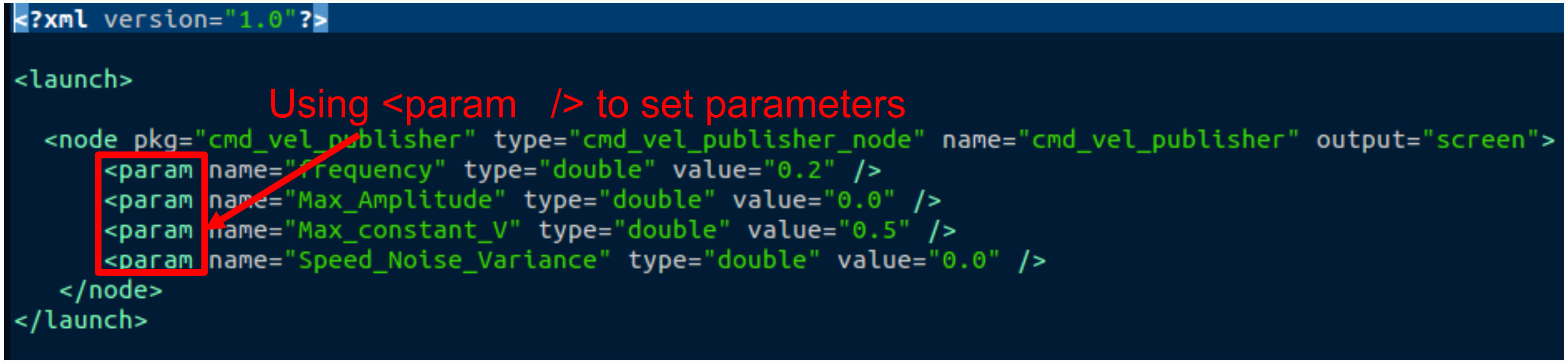
- If roslaunch is used, roscore does not need to be run manually.

Launch Files are like Startup Scripts



Launch file example

A launch file for launching a node with many parameters



```
<?xml version="1.0"?>

<launch>

  <node pkg="cmd_vel_publisher" type="cmd_vel_publisher_node" name="cmd_vel_publisher" output="screen">
      <param name="frequency" type="double" value="0.2" />
      <param name="Max_Amplitude" type="double" value="0.0" />
      <param name="Max_constant_V" type="double" value="0.5" />
      <param name="Speed_Noise_Variance" type="double" value="0.0" />
   </node>
</launch>
```

To run a launch file use:

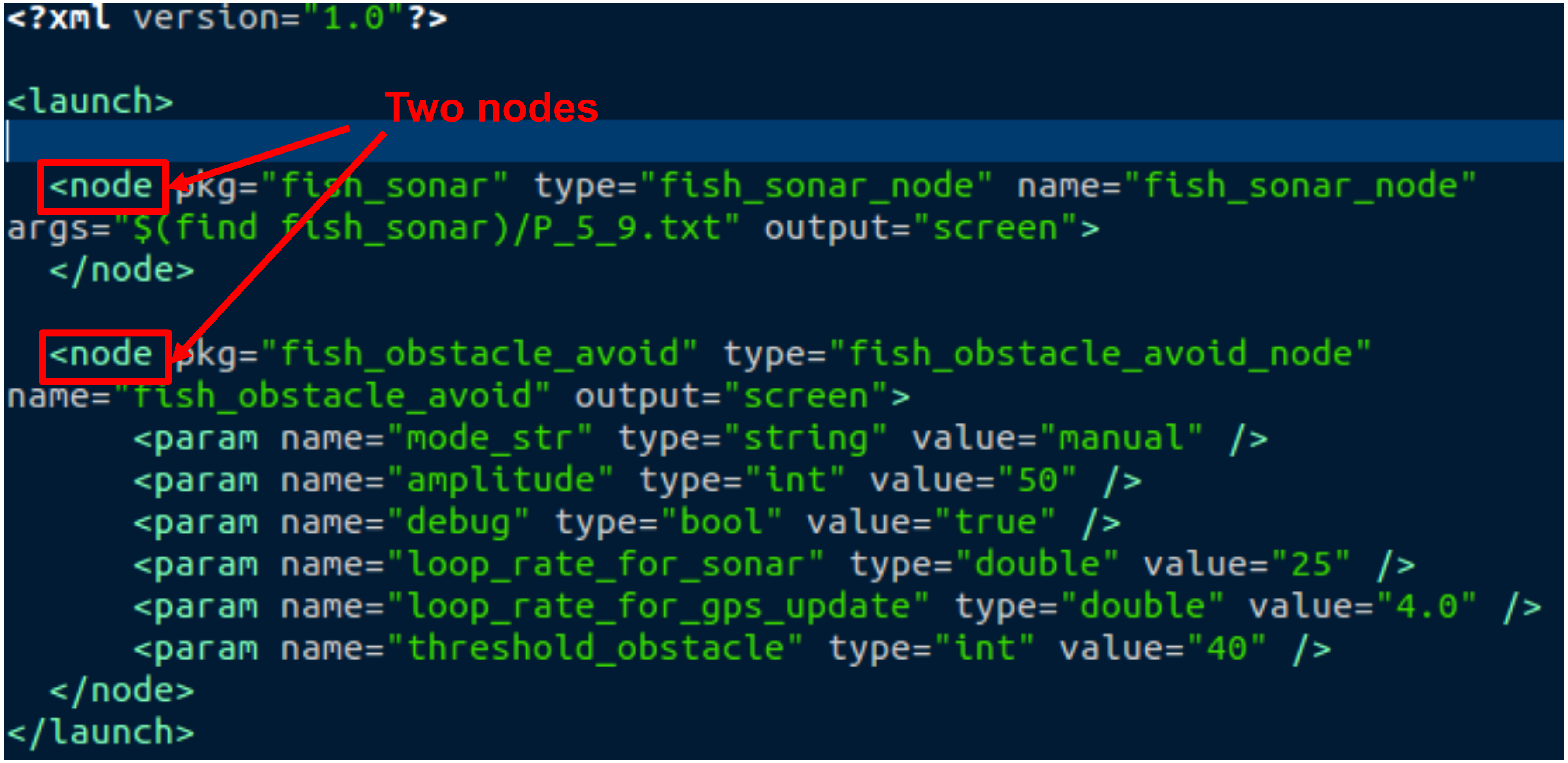
```
$ roslaunch package_name file.launch
```

For the above example:

```
$ roslaunch cmd_vel_publisher cmd_vel_publisher.launch
```

Launch file example

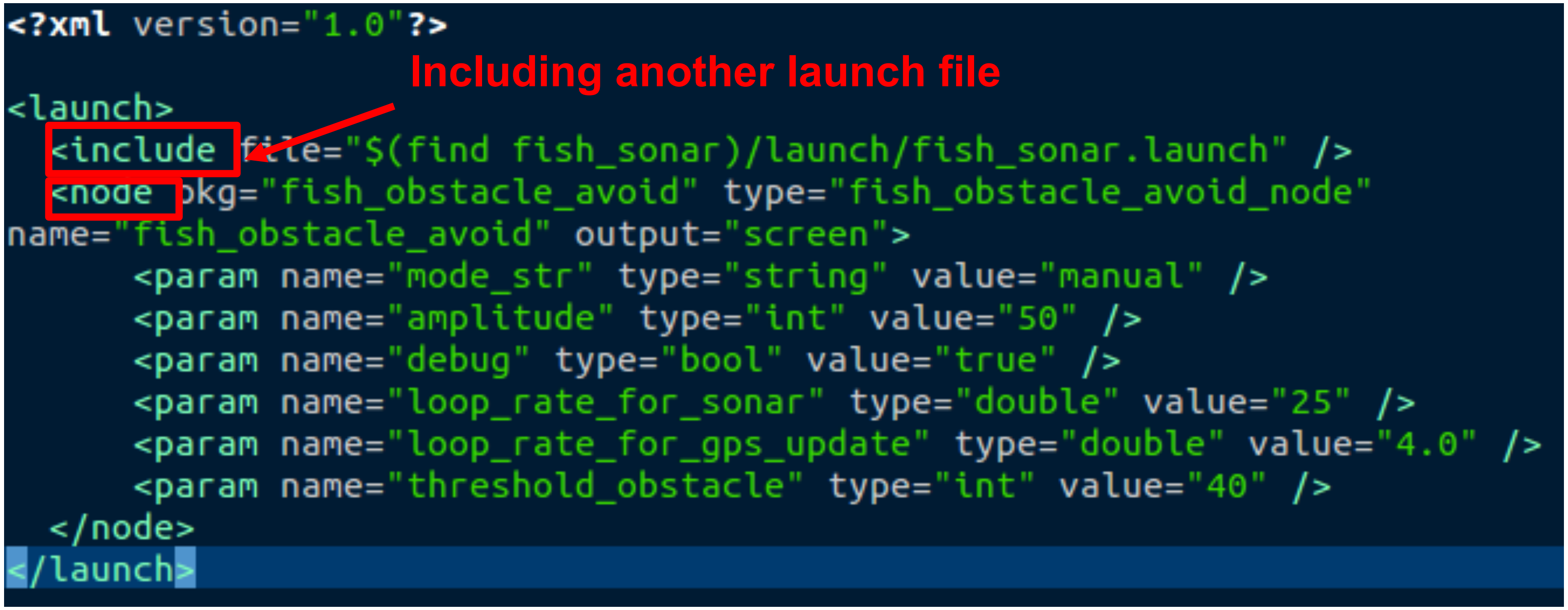
A launch file for launching two or more nodes simultaneously



```
<?xml version="1.0"?>

<launch>

  <node pkg="fish_sonar" type="fish_sonar_node" name="fish_sonar_node"
args="$(find fish_sonar)/P_5_9.txt" output="screen">
  </node>

  <node pkg="fish_obstacle_avoid" type="fish_obstacle_avoid_node"
name="fish_obstacle_avoid" output="screen">
      <param name="mode_str" type="string" value="manual" />
      <param name="amplitude" type="int" value="50" />
      <param name="debug" type="bool" value="true" />
      <param name="loop_rate_for_sonar" type="double" value="25" />
      <param name="loop_rate_for_gps_update" type="double" value="4.0" />
      <param name="threshold_obstacle" type="int" value="40" />
  </node>
</launch>
```

Launch file example

A launch file for launching two or more nodes by including another launch file



```
<?xml version="1.0"?>

<launch>
  <include file="$(find fish_sonar)/launch/fish_sonar.launch" />
  <node pkg="fish_obstacle_avoid" type="fish_obstacle_avoid_node"
name="fish_obstacle_avoid" output="screen">
      <param name="mode_str" type="string" value="manual" />
      <param name="amplitude" type="int" value="50" />
      <param name="debug" type="bool" value="true" />
      <param name="loop_rate_for_sonar" type="double" value="25" />
      <param name="loop_rate_for_gps_update" type="double" value="4.0" />
      <param name="threshold_obstacle" type="int" value="40" />
  </node>
</launch>
```

Advanced Launchfiles

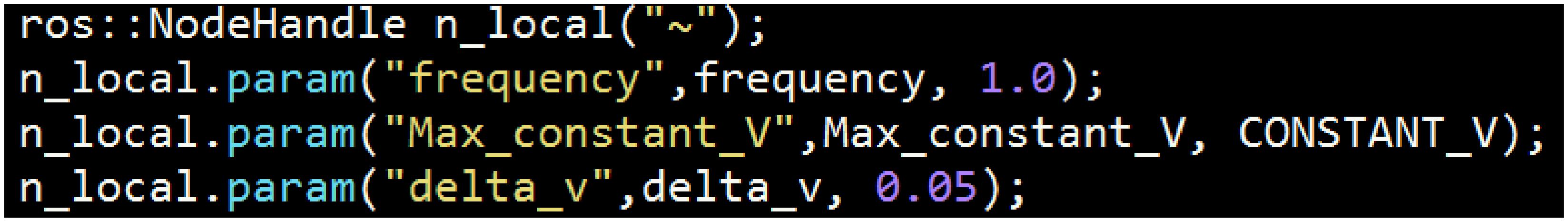
- **`<arg>`** – Pass a value into a launch file
- **`if=`** or **`unless=`** – Conditional branching
  - *extremely limited. True/False only (no comparisons).*
- **`<group>`** – group commands, for if/unless or namespace
- **`<remap>`** – rename topics/services/etc.

```
<launch>
  <arg name="robot" default="sia20" />
  <arg name="show_rviz" default="true" />
  <group ns="robot" >
    <include file="$(find lesson)/launch/load_$(arg robot)_data.launch" />
     <remap from="joint_trajectory_action" to="command" />
  </group>
  <node name="rviz" pkg="rviz" type="rviz" if="$(arg show_rviz)" />
</launch>
```

Retrieving Parameters in c++ file

- There are two methods to retrieve parameters with NodeHandle:
  - getParam(key, output_value)
  - param(key, output_value,default) is similar to getParam(), but allows to specify a default value
  - key: ”~…” is in the private namespace…

- Example: in the cpp file

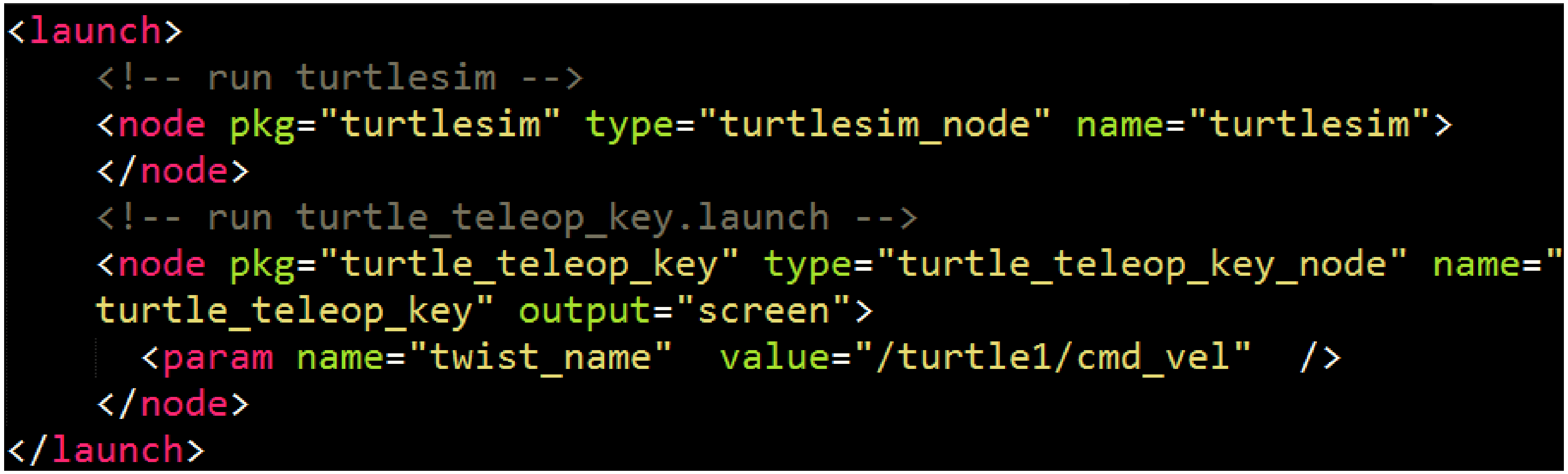


```
ros::NodeHandle n_local("~");
n_local.param("frequency",frequency, 1.0);
n_local.param("Max_constant_V",Max_constant_V, CONSTANT_V);
n_local.param("delta_v",delta_v, 0.05);
```

Try: Launch

- Use launch file to run two nodes with params
  - Run turtlesim and its velocity control

- Solution:



```
<launch>
    <!-- run turtlesim -->
    <node pkg="turtlesim" type="turtlesim_node" name="turtlesim">
    </node>
    <!-- run turtle_teleop_key.launch -->
    <node pkg="turtle_teleop_key" type="turtle_teleop_key_node" name="
    turtle_teleop_key" output="screen">
      <param name="twist_name"  value="/turtle1/cmd_vel"  />
    </node>
</launch>
```

Important ROS tools

- Rviz: show live data, including video, TF, Point Clouds, Maps, Robot Models …
  - http://wiki.ros.org/rviz/Tutorials
- rosbag: record messages into a (bag-) file! Ability to replay those bagfiles!
  - http://wiki.ros.org/rosbag/Tutorials/Recording%20and%20playing%20back%20data
- rqt_bag: visualize the contents of a bagfile
- rqt_graph: show in a GUI with which topics nodes are connected
- rqt_console: show debug, warning and error messages – good filters
- rosrun rqt_reconfigure rqt_reconfigure package: re-configure parameters on the fly using a GUI!
- roswtf: see if there are problems with your currently running ROS system

Recourses:

- http://wiki.ros.org/ROS/Tutorials/
- https://en.wikipedia.org/wiki/Object-oriented_programming
- C++: http://www.cplusplus.com/doc/tutorial/
  - http://www.cplusplus.com/doc/tutorial/templates/
- https://en.wikipedia.org/wiki/Smart_pointer
  - http://en.cppreference.com/w/cpp/memory/shared_ptr
- http://www.cprogramming.com/tutorial/const_correctness.html

Cheat Sheets

- http://sist.shanghaitech.edu.cn/faculty/soerensch/mobile_robotics_2014/cheat_cheets/**bash_cheat_sheet.pdf**
- http://sist.shanghaitech.edu.cn/faculty/soerensch/mobile_robotics_2014/cheat_cheets/**gitCheatCheet.pdf**
- http://sist.shanghaitech.edu.cn/faculty/soerensch/mobile_robotics_2014/cheat_cheets/**vim-cheat-sheet.png**
- http://sist.shanghaitech.edu.cn/faculty/soerensch/mobile_robotics_2014/cheat_cheets/**regular_expressions_cheat_sheet.png**
- http://sist.shanghaitech.edu.cn/faculty/soerensch/mobile_robotics_2014/cheat_cheets/**cpp_reference_sheet.pdf**
- http://sist.shanghaitech.edu.cn/faculty/soerensch/mobile_robotics_2014/cheat_cheets/**ROScheatsheet.pdf**
- http://sist.shanghaitech.edu.cn/faculty/soerensch/mobile_robotics_2014/cheat_cheets/**ROS-Cheat-Sheet-Landscape-v2.pdf**

Questions?