ETH zürich

Programming for Robotics
Introduction to ROS

Course 2

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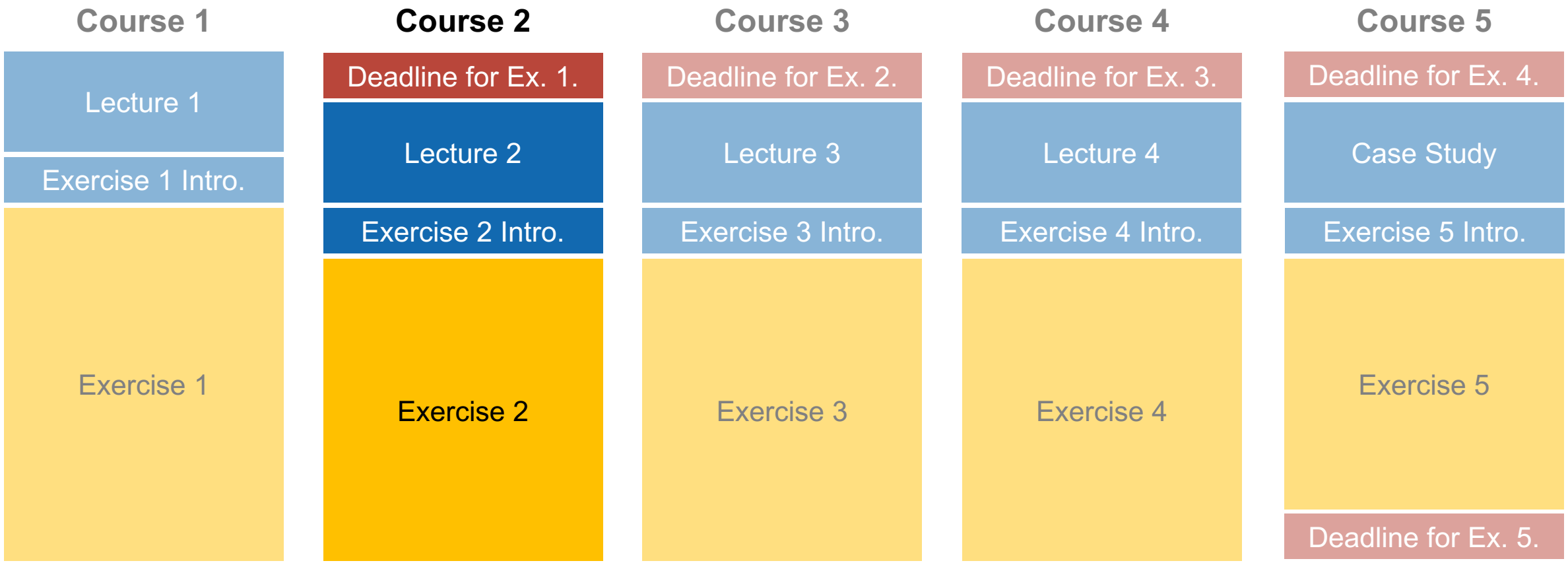
ROS

RSL Robotic Systems Lab

Course Structure



Overview Course 2

- ROS package structure
- Integration and programming with Eclipse
- ROS C++ client library (roscpp)
- ROS subscribers and publishers
- ROS parameter server
- RViz visualization

ROS Packages

- ROS software is organized into *packages*, which can contain source code, launch files, configuration files, message definitions, data, and documentation
- A package that builds up on/requires other packages (e.g. message definitions), declares these as *dependencies*

To create a new package, use

```
> catkin_create_pkg package_name
    {dependencies}
```

Separate message definition packages from other packages!

package_name

- **config**
  Parameter files (YAML)
- **include/*package_name***
  C++ include headers
- **launch**
  *.launch files
- **src**
  Source files
- **test**
  Unit/ROS tests
- **CMakeLists.txt**
  CMake build file
- **package.xml**
  Package information

package_name_msgs

- **action**
  Action definitions
- **msg**
  Message definitions
- **srv**
  Service definitions
- **CMakeLists.txt**
  Cmake build file
- **package.xml**
  Package information

More info
http://wiki.ros.org/Packages

ROS Packages
package.xml

- The `package.xml` file defines the properties of the package
  - Package name
  - Version number
  - Authors
  - **Dependencies on other packages**
  - …

package.xml

```
<?xml version="1.0"?>
<package format="2">
  <name>ros_package_template</name>
  <version>0.1.0</version>
  <description>A template for ROS packages.</description>
  <maintainer email="pfankhauser@e…">Peter Fankhauser</maintainer>
  <license>BSD</license>
  <url type="website">https://github.com/ethz-asl/ros_best_pr…</url>
  <author email="pfankhauser@ethz.ch">Peter Fankhauser</author>

  <buildtool_depend>catkin</buildtool_depend>

  <depend>roscpp</depend>
  <depend>sensor_msgs</depend>
</package>
```

More info
http://wiki.ros.org/catkin/package.xml

ROS Packages
CMakeLists.xml

The `CMakeLists.txt` is the input to the CMakebuild system

1. Required CMake Version (`cmake_minimum_required`)
2. Package Name (`project()`)
3. Find other CMake/Catkin packages needed for build (`find_package()`)
4. Message/Service/Action Generators (`add_message_files()`, `add_service_files()`, `add_action_files()`)
5. Invoke message/service/action generation (`generate_messages()`)
6. Specify package build info export (`catkin_package()`)
7. Libraries/Executables to build (`add_library()`/`add_executable()`/`target_link_libraries()`)
8. Tests to build (`catkin_add_gtest()`)
9. Install rules (`install()`)

CMakeLists.txt

```
cmake_minimum_required(VERSION 2.8.3)
project(ros_package_template)

## Use C++11
add_definitions(--std=c++11)

## Find catkin macros and libraries
find_package(catkin REQUIRED
  COMPONENTS
    roscpp
    sensor_msgs
)

…
```

More info
http://wiki.ros.org/catkin/CMakeLists.txt

ROS Packages
CMakeLists.xml Example

```
cmake_minimum_required(VERSION 2.8.3)
project(husky_highlevel_controller)
add_definitions(--std=c++11)

find_package(catkin REQUIRED
  COMPONENTS roscpp sensor_msgs
)

catkin_package(
  INCLUDE_DIRS include
  # LIBRARIES
  CATKIN_DEPENDS roscpp sensor_msgs
  # DEPENDS
)

include_directories(include ${catkin_INCLUDE_DIRS})

add_executable(${PROJECT_NAME} src/${PROJECT_NAME}_node.cpp
src/HuskyHighlevelController.cpp)

target_link_libraries(${PROJECT_NAME} ${catkin_LIBRARIES})
```

Use the same name as in the `package.xml`

We use C++11 by default

List the packages that your package requires to build (have to be listed in `package.xml`)

Specify build export information

- `INCLUDE_DIRS`: Directories with header files
- `LIBRARIES`: Libraries created in this project
- `CATKIN_DEPENDS`: Packages dependent projects also need
- `DEPENDS`: System dependencies dependent projects also need (have to be listed in `package.xml`)

Specify locations of of header files

Declare a C++ executable

Specify libraries to link the executable against

Setup a Project in Eclipse

- Build the Eclipse project files with additional build flags

```
> catkin build package_name -G"Eclipse CDT4 - Unix Makefiles”
  -D__cplusplus=201103L -D__GXX_EXPERIMENTAL_CXX0X__=1
```

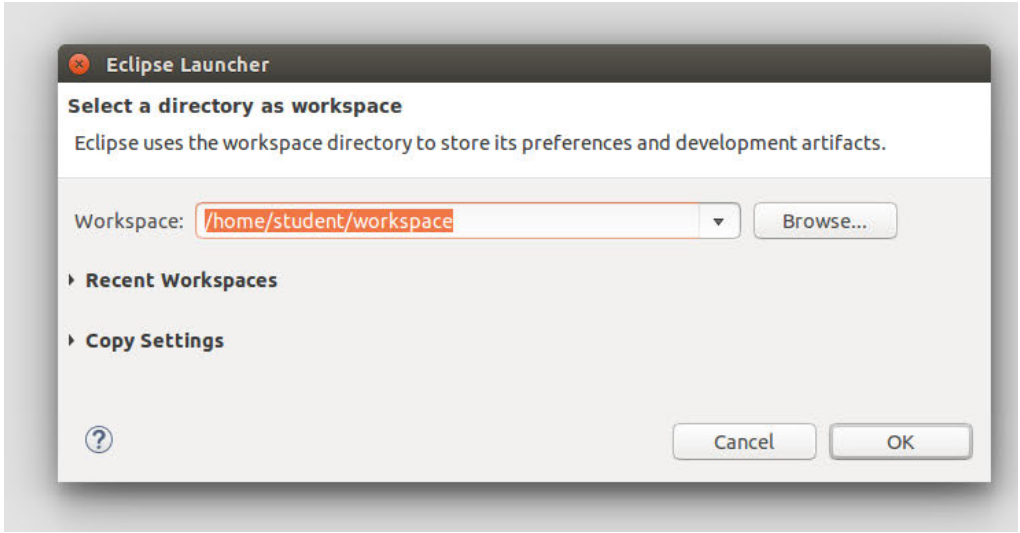
- To use flags by default in your catkin environment, use the `catkin config` command.
- The Eclipse project files will be generated in `~/catkin_ws/build`

The build flags are already setup in the provided installation.

More info
http://catkin-tools.readthedocs.io/en/latest/verbs/catkin_config.html
https://github.com/ethz-asl/ros_best_practices/wiki#catkin-build-flags

Setup a Project in Eclipse

- Start Eclipse and set the workspace folder

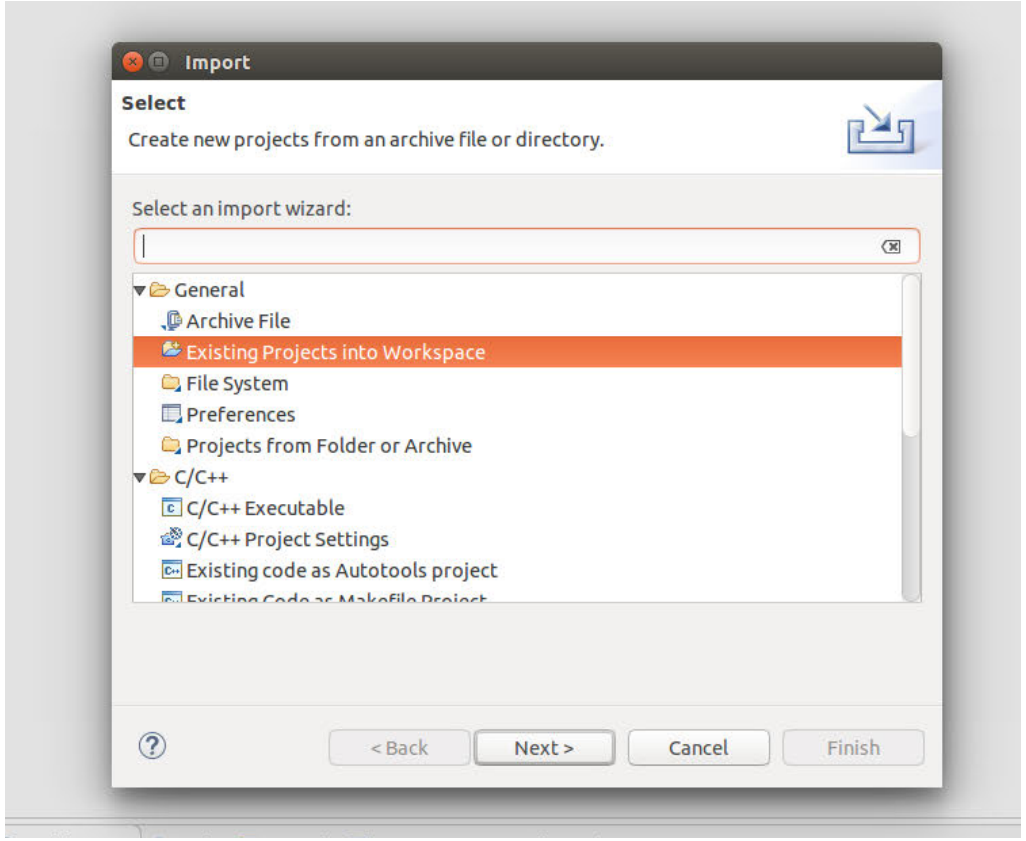


The Eclipse workspace is already set in the provided installation.

Setup a Project in Eclipse

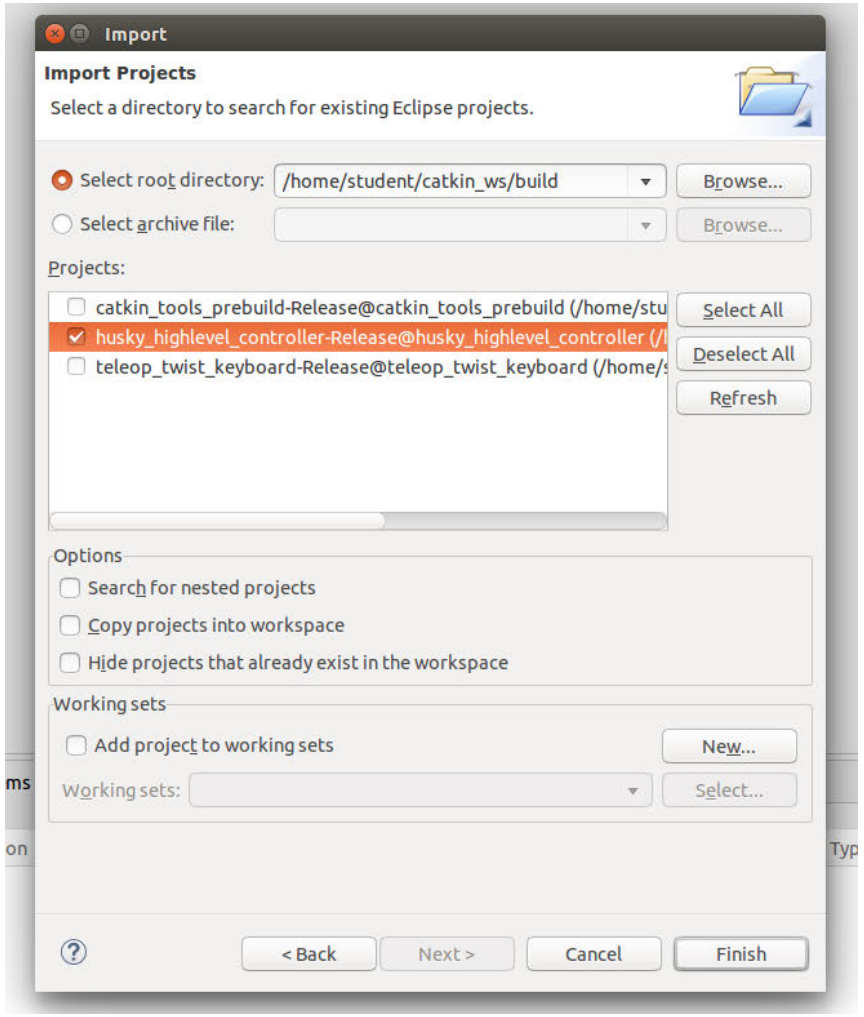
- Import your project to Eclipse

  File → Import → General
  → Existing Projects into Workspace



Setup a Project in Eclipse

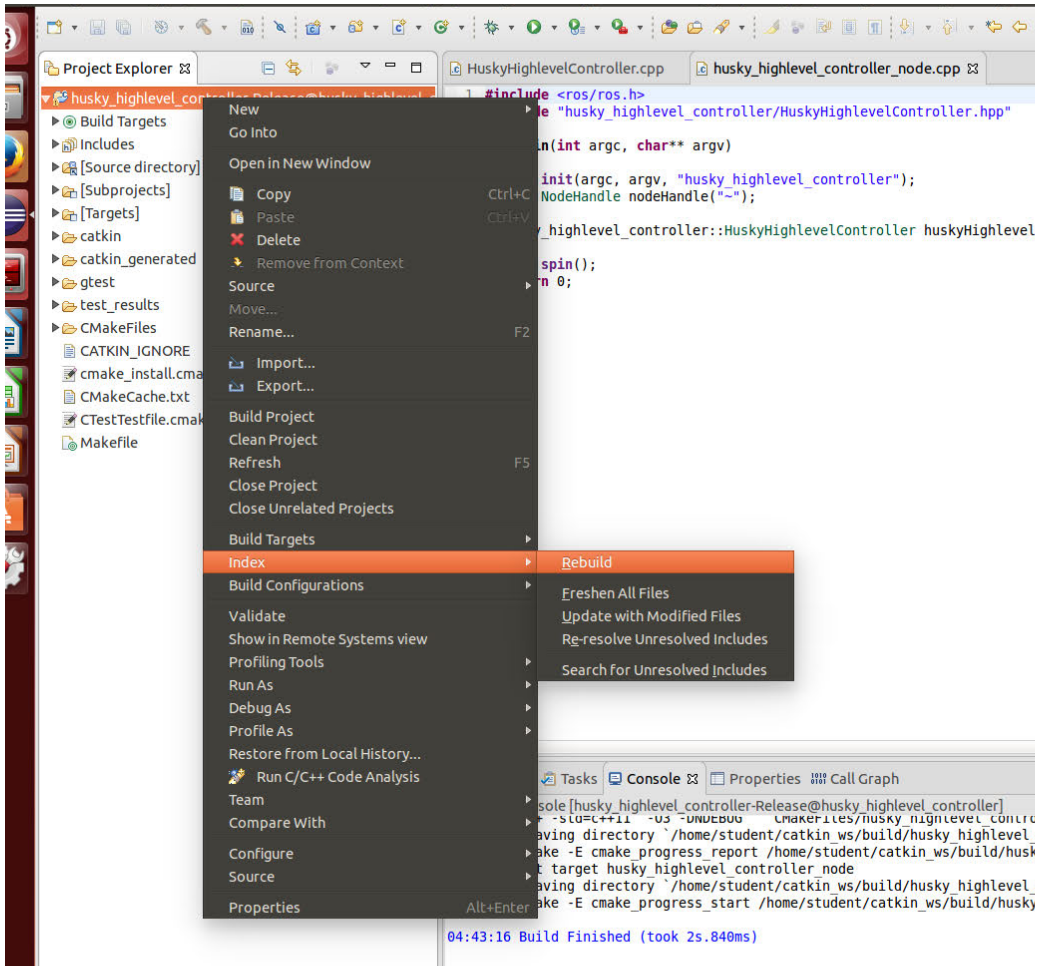
- The project files can be imported from the `~/catkin_ws/build` folder



Setup a Project in Eclipse

- Rebuild the C/C++ index of your project by Right click on Project → Index → Rebuild

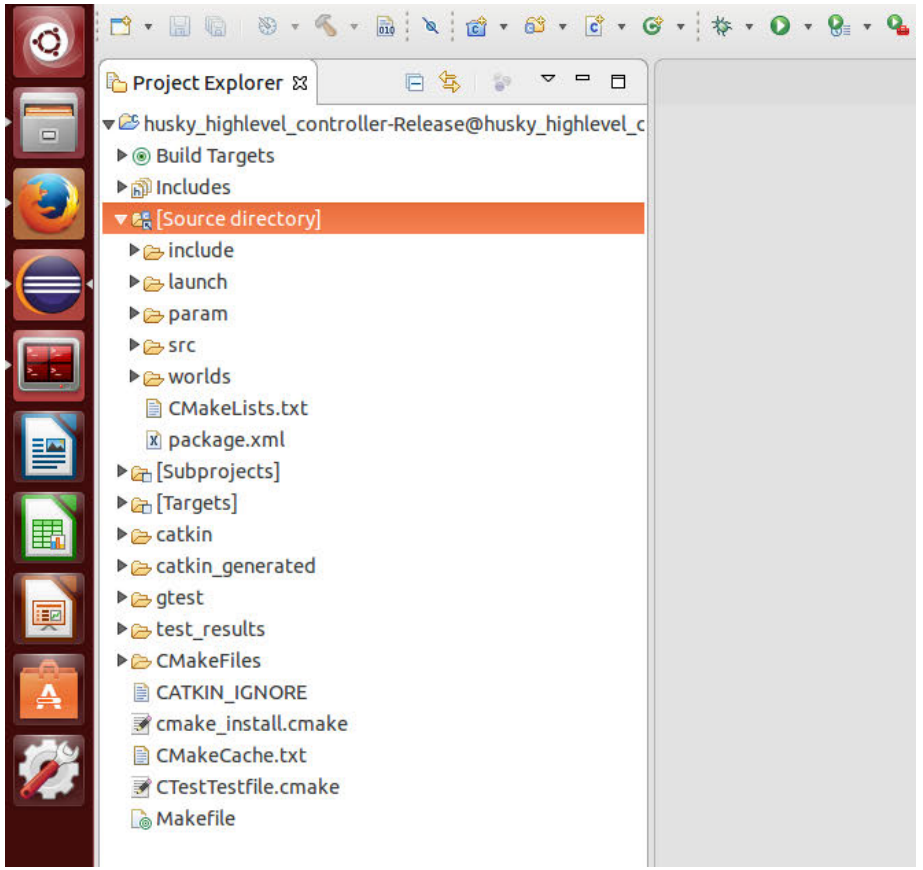
- Resolving the includes enables
  - Fast navigation through links (`Ctrl` + click)
  - Auto-completion (`Ctrl` + `Space`)
  - Building (`Ctrl` + `B`) and debugging your code in Eclipse



Setup a Project in Eclipse

- Within the project a link `[Source directory]` is provided such that you can edit your project

- Useful Eclipse shortcuts
  - `Ctrl` + `Space`: Auto-complete
  - `Ctrl` + `/`: Comment / uncomment line or section
  - `Ctrl` + `Shift` + `F`: Auto-format code using code formatter
  - `Alt` + `Arrow Up / Arrow Down`: Move line or selection up or down
  - `Ctrl` + `D`: Delete line



ROS C++ Client Library (*roscpp*)

hello_world.cpp

```
#include <ros/ros.h>

int main(int argc, char** argv)
{
  ros::init(argc, argv, "hello_world");
  ros::NodeHandle nodeHandle;
  ros::Rate loopRate(10);

  unsigned int count = 0;
  while (ros::ok()) {
    ROS_INFO_STREAM("Hello World " << count);
    ros::spinOnce();
    loopRate.sleep();
    count++;
  }

  return 0;
}
```

ROS main header file include

`ros::init(…)` has to be called before calling other ROS functions

The node handle is the access point for communications with the ROS system (topics, services, parameters)

`ros::Rate` is a helper class to run loops at a desired frequency

`ros::ok()` checks if a node should continue running
Returns `false` if `SIGINT` is received (`Ctrl` + `C`) or `ros::shutdown()` has been called

`ROS_INFO()` logs messages to the filesystem

`ros::spinOnce()` processes incoming messages via callbacks

More info
http://wiki.ros.org/roscpp
http://wiki.ros.org/roscpp/Overview

ROS C++ Client Library (*roscpp*)
Node Handle

- There are four main types of node handles

1. Default (public) node handle:
   `nh_ = ros::NodeHandle();`
2. Private node handle:
   `nh_private_ = ros::NodeHandle("~");`
3. Namespaced node handle:
   `nh_eth_ = ros::NodeHandle("eth");`
4. Global node handle:
   `nh_global_ = ros::NodeHandle("/");`

Recommended

Not recommended

For a ***node*** in ***namespace*** looking up ***topic***, these will resolve to:

```
/namespace/topic

/namespace/node/topic

/namespace/eth/topic

/topic
```

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

ROS C++ Client Library (*roscpp*)
Logging

- Mechanism for logging human readable text from nodes in the console and to log files
- Instead of `std::cout`, use e.g. `ROS_INFO`
- Automatic logging to console, log file, and `/rosout` topic
- Different severity levels (Info, Warn, Error etc.)
- Supports both printf- and stream-style formatting

```
ROS_INFO("Result: %d", result);
ROS_INFO_STREAM("Result: " << result);
```

- Further features such as conditional, throttled, delayed logging etc.

	Debug	Info	Warn	Error	Fatal
stdout	x	x			
stderr			x	x	x
Log file	x	x	x	x	x
/rosout	x	x	x	x	x

! To see the output in the console, set the output configuration to `screen` in the launch file

```
<launch>
    <node name="listener" ... output="screen"/>
</launch>
```

More info
http://wiki.ros.org/rosconsole
http://wiki.ros.org/roscpp/Overview/Logging

ROS C++ Client Library (*roscpp*)
Subscriber

- Start listening to a topic by calling the method `subscribe()` of the node handle

```
ros::Subscriber subscriber =
nodeHandle.subscribe(topic, queue_size,
                     callback_function);
```

- When a message is received, callback function is called with the contents of the message as argument
- Hold on to the subscriber object until you want to unsubscribe

`ros::spin()` processes callbacks and will not return until the node has been shutdown

listener.cpp

```
#include "ros/ros.h"
#include "std_msgs/String.h"

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

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

  ros::Subscriber subscriber =
       nodeHandle.subscribe("chatter",10,chatterCallback);
  ros::spin();
  return 0;
}
```

More info
http://wiki.ros.org/roscpp/Overview/Publishers%20and%20Subscribers

ROS C++ Client Library (*roscpp*)
Publisher

- Create a publisher with help of the node handle

```
ros::Publisher publisher =
nodeHandle.advertise<message_type>(topic,
queue_size);
```

- Create the message contents
- Publish the contents with

```
publisher.publish(message);
```

talker.cpp

```
#include <ros/ros.h>
#include <std_msgs/String.h>

int main(int argc, char **argv) {
  ros::init(argc, argv, "talker");
  ros::NodeHandle nh;
  ros::Publisher chatterPublisher =
    nh.advertise<std_msgs::String>("chatter", 1);
  ros::Rate loopRate(10);

  unsigned int count = 0;
  while (ros::ok()) {
    std_msgs::String message;
    message.data = "hello world " + std::to_string(count);
    ROS_INFO_STREAM(message.data);
    chatterPublisher.publish(message);
    ros::spinOnce();
    loopRate.sleep();
    count++;
  }
  return 0;
}
```

More info
http://wiki.ros.org/roscpp/Overview/Publishers%20and%20Subscribers

ROS C++ Client Library (*roscpp*)

Object Oriented Programming

my_package_node.cpp

```
#include <ros/ros.h>
#include "my_package/MyPackage.hpp"
int main(int argc, char** argv)
{
  ros::init(argc, argv, "my_package");
  ros::NodeHandle nodeHandle("~");

  my_package::MyPackage myPackage(nodeHandle);

  ros::spin();
  return 0;
}
```

MyPackage.hpp

MyPackage.cpp

`class MyPackage`

Main node class providing ROS interface (subscribers, parameters, timers etc.)

Algorithm.hpp

Algorithm.cpp

`class Algorithm`

Class implementing the algorithmic part of the node

Note: The algorithmic part of the code could be separated in a (ROS-independent) library

! Specify a function handler to a method from within the class as

```
subscriber_ = nodeHandle_.subscribe(topic, queue_size,
&ClassName::methodName, this);
```

More info
http://wiki.ros.org/roscpp_tutorials/Tutorials/UsingClassMethodsAsCallbacks

ROS Parameter Server

- Nodes use the *parameter server* to store and retrieve parameters at runtime
- Best used for static data such as configuration parameters
- Parameters can be defined in launch files or separate *YAML* files

List all parameters with

```
> rosparam list
```

Get the value of a parameter with

```
> rosparam get parameter_name
```

Set the value of a parameter with

```
> rosparam set parameter_name value
```

config.yaml

```
camera:
  left:
    name: left_camera
    exposure: 1
  right:
    name: right_camera
    exposure: 1.1
```

package.launch

```
<launch>
  <node name="name" pkg="package" type="node_type">
      <rosparam command="load"
                file="$(find package)/config/config.yaml" />
  </node>
</launch>
```

More info
http://wiki.ros.org/rosparam

ROS Parameter Server
C++ API

- Get a parameter in C++ with

```
nodeHandle.getParam(parameter_name, variable)
```

- Method returns `true` if parameter was found, `false` otherwise
- Global and relative parameter access:
  - Global parameter name with preceding `/`

```
nodeHandle.getParam("/package/camera/left/exposure", variable)
```

  - Relative parameter name (relative to the node handle)

```
nodeHandle.getParam("camera/left/exposure", variable)
```

- For parameters, typically use the private node handle `ros::NodeHandle("~")`

```
ros::NodeHandle nodeHandle("~");
std::string topic;
if (!nodeHandle.getParam("topic", topic)) {
  ROS_ERROR("Could not find topic
             parameter!");
}
```

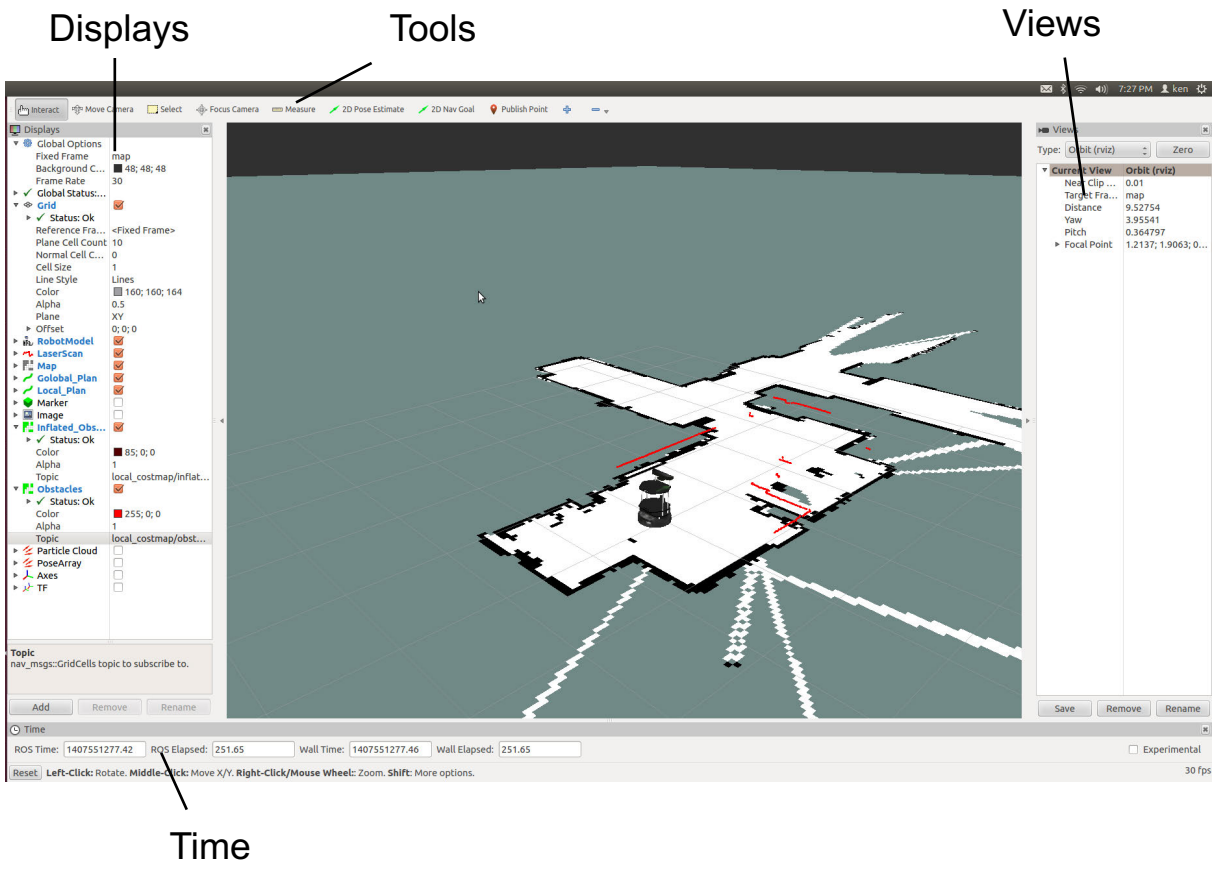
More info
http://wiki.ros.org/roscpp/Overview/Parameter%20Server

RViz

- 3D visualization tool for ROS
- Subscribes to topics and visualizes the message contents
- Different camera views (orthographic, top-down, etc.)
- Interactive tools to publish user information
- Save and load setup as RViz configuration
- Extensible with plugins

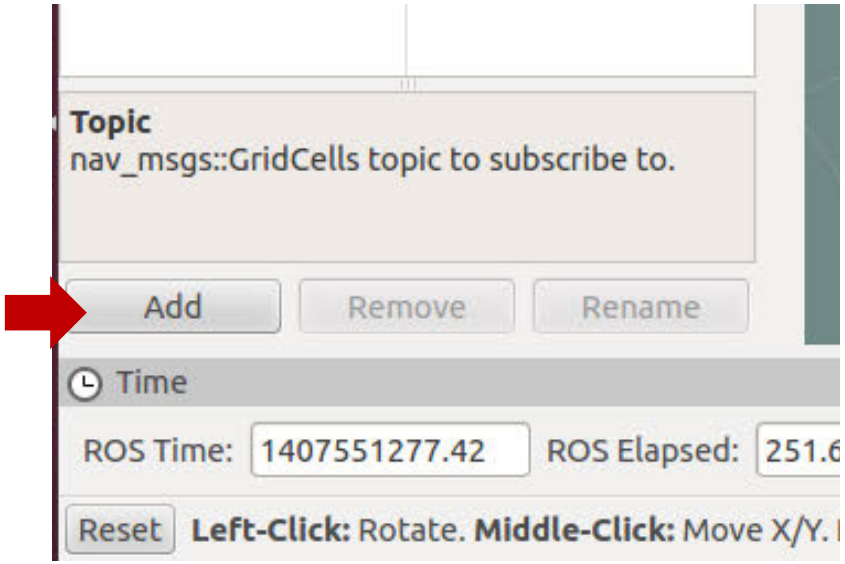
Run RViz with

```
> rosrun rviz rviz
```



More info
http://wiki.ros.org/rviz

RViz
Display Plugins



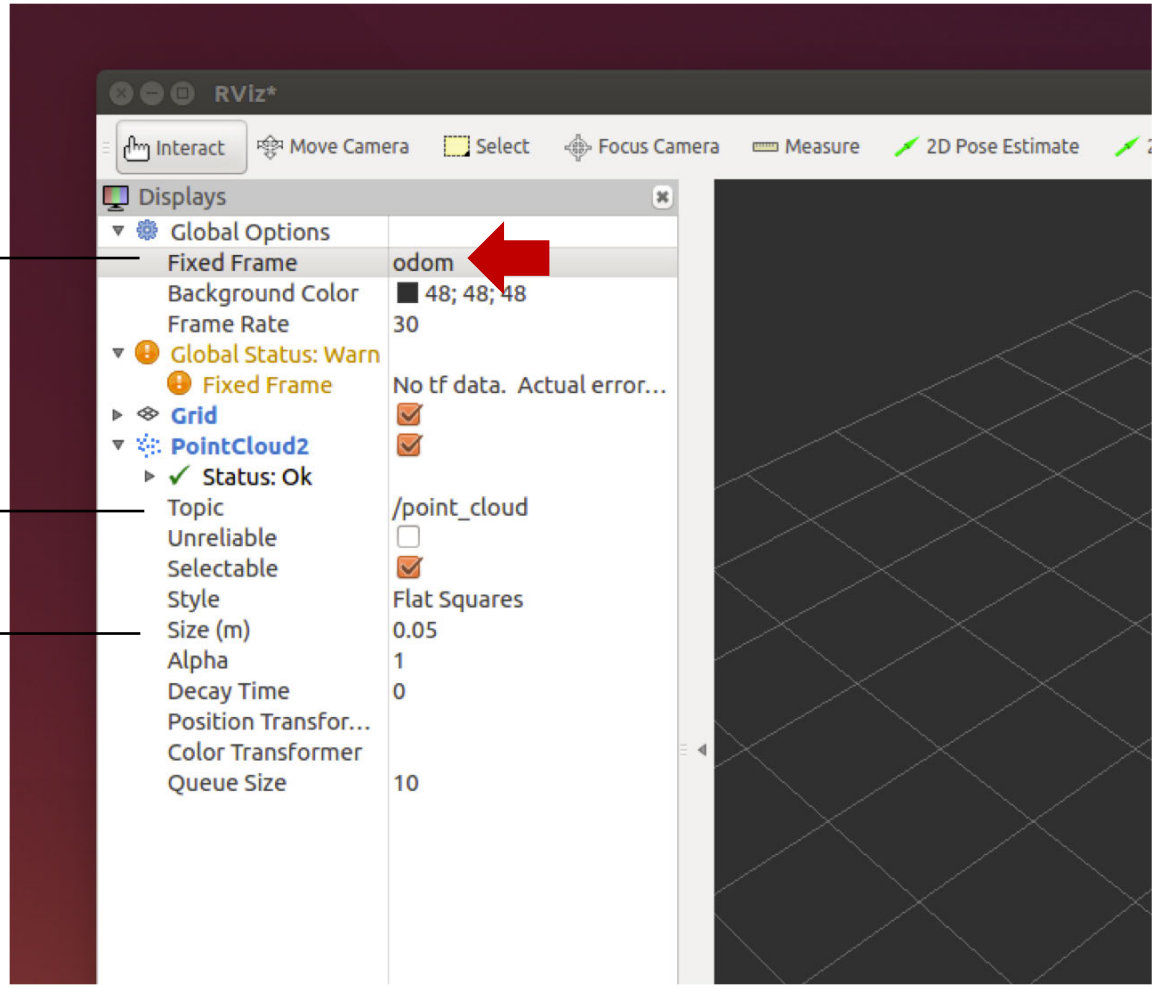
- Axes
- Camera
- DepthCloud
- Effort
- FluidPressure
- Grid
- GridCells
- Group
- Illuminance
- Image
- InteractiveMarkers
- LaserScan
- Map
- Marker
- MarkerArray
- Odometry
- Path
- PointCloud
- PointCloud2
- PointStamped
- Polygon
- Pose
- PoseArray
- Range
- RelativeHumidity
- RobotModel
- TF
- Temperature
- WrenchStamped

RViz
Visualizing Point Clouds Example

! Frame in which the data is displayed (has to exist!)

Choose the topic for the display

Change the display options (e.g. size)



Further References

- **ROS Wiki**
  - http://wiki.ros.org/
- **Installation**
  - http://wiki.ros.org/ROS/Installation
- **Tutorials**
  - http://wiki.ros.org/ROS/Tutorials
- **Available packages**
  - http://www.ros.org/browse/
- **ROS Cheat Sheet**
  - https://github.com/ros/cheatsheet/releases/download/0.0.1/ROScheatsheet_catkin.pdf
- **ROS Best Practices**
  - https://github.com/ethz-asl/ros_best_practices/wiki
- **ROS Package Template**
  - https://github.com/ethz-asl/ros_best_practices/tree/master/ros_package_template

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Course website:
http://www.rsl.ethz.ch/education-students/lectures/ros.html