



Programming for Robotics

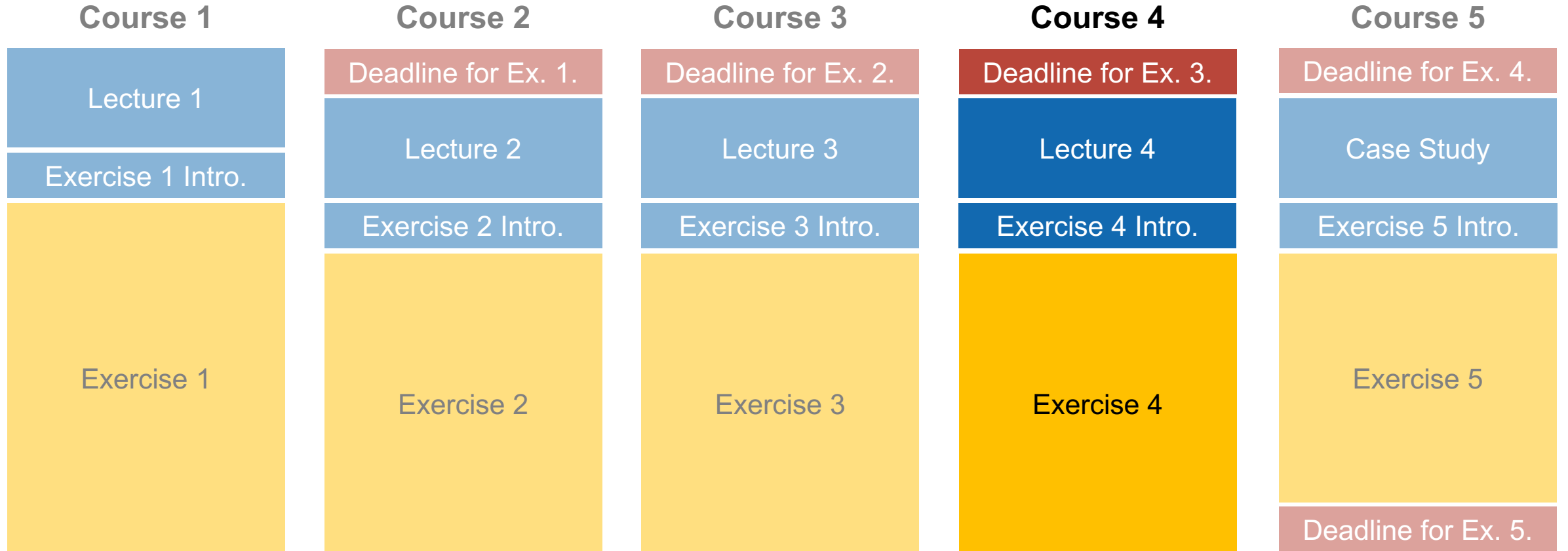
Introduction to ROS

Course 4

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Course Structure



Overview Course 4

- ROS services
- ROS actions (actionlib)
- ROS time
- ROS bags
- Debugging strategies

ROS Services

- Request/response communication between nodes is realized with *services*
 - The *service server* advertises the service
 - The *service client* accesses this service
- Similar in structure to messages, services are defined in **.srv* files

List available services with

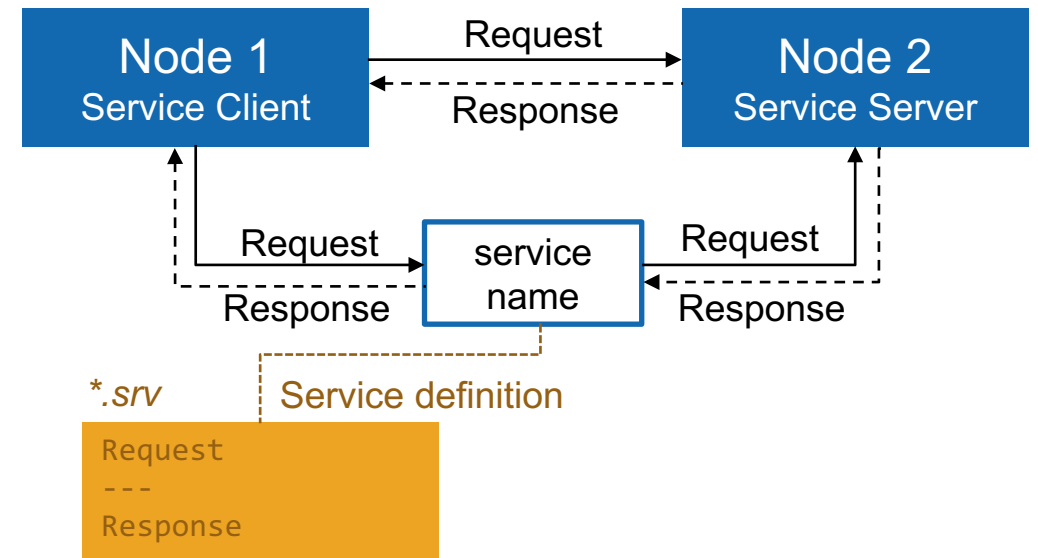
```
> rosservice list
```

Show the type of a service

```
> rosservice type /service_name
```

Call a service with the request contents

```
> rosservice call /service_name args
```



More info

<http://wiki.ros.org/Services>

ROS Services

Examples

std_srvs/Trigger.srv

```
---  
bool success  
string message
```

Request

Response

nav_msgs/GetPlan.srv

```
geometry_msgs/PoseStamped start  
geometry_msgs/PoseStamped goal  
float32 tolerance  
---  
nav_msgs/Path plan
```

ROS Service Example

Starting a *roscore* and a *add_two_ints_server* node

In console nr. 1:

Start a roscore with

```
> roscore
```

In console nr. 2:

Run a service demo node with

```
> rosruncpp_tutorials add_two_ints_server
```

```
PARAMETERS
* /roscpp_tutorials: indigo
* /roscpp_tutorials: 1.11.20

NODES

auto-starting new master
process[master]: started with pid [6708]
ROS_MASTER_URI=http://ubuntu:11311/

setting /run_id to 6c1852aa-e961-11e6-8543-000c297bd368
process[roscpp_tutorials-1]: started with pid [6721]
started core service [/roscpp_tutorials]
```

```
student@ubuntu:~$ rosruncpp_tutorials add_two_ints_server
```

ROS Service Example

Console Nr. 3 – Analyze and call service

See the available services with

```
> rosservice list
```

```
student@ubuntu:~$ 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
```

See the type of the service with

```
> rosservice type /add_two_ints
```

```
student@ubuntu:~$ rosservice type /add_two_ints
roscpp_tutorials/TwoInts
```

Show the service definition with

```
> rossrv show roscpp_tutorials/TwoInts
```

```
student@ubuntu:~$ rossrv show roscpp_tutorials/TwoInts
int64 a
int64 b
---
int64 sum
```

Call the service (use Tab for auto-complete)

```
> rosservice call /add_two_ints "a: 10
b: 5"
```

```
student@ubuntu:~$ rosservice call /add_two_ints "a: 10
b: 5"
sum: 15
```

ROS C++ Client Library (*roscpp*)

Service Server

- Create a service server with


```
ros::ServiceServer service =
  nodeHandle.advertiseService(service_name,
                              callback_function);
```
- When a service request is received, callback function is called with the request as argument
- Fill in the response to the response argument
- Return to function with true to indicate that it has been executed properly

add_two_ints_server.cpp

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

bool add(roscpp_tutorials::TwoInts::Request &request,
         roscpp_tutorials::TwoInts::Response &response)
{
  response.sum = request.a + request.b;
  ROS_INFO("request: x=%ld, y=%ld", (long int)request.a,
           (long int)request.b);
  ROS_INFO(" sending back response: [%ld]",
           (long int)response.sum);
  return true;
}

int main(int argc, char **argv)
{
  ros::init(argc, argv, "add_two_ints_server");
  ros::NodeHandle nh;
  ros::ServiceServer service =
    nh.advertiseService("add_two_ints", add);
  ros::spin();
  return 0;
}
```

More info

<http://wiki.ros.org/roscpp/Overview/Services>

ROS C++ Client Library (*roscpp*)

Service Client

- Create a service client with

```
ros::ServiceClient client =
  nodeHandle.serviceClient<service_type>
    (service_name);
```

- Create service request contents
`service.request`

- Call service with

```
client.call(service);
```

- Response is stored in `service.response`

More info

<http://wiki.ros.org/roscpp/Overview/Services>

add_two_ints_client.cpp

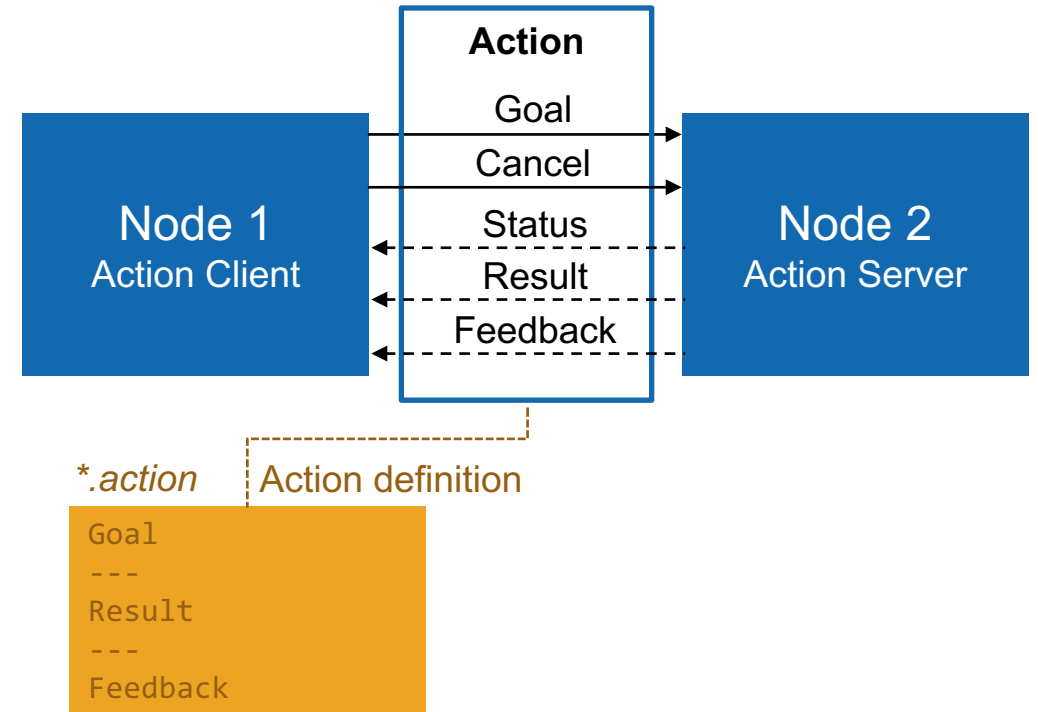
```
#include <ros/ros.h>
#include <roscpp_tutorials/TwoInts.h>
#include <cstdlib>

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 nh;
  ros::ServiceClient client =
    nh.serviceClient<roscpp_tutorials::TwoInts>("add_two_ints");
  roscpp_tutorials::TwoInts service;
  service.request.a = atoi(argv[1]);
  service.request.b = atoi(argv[2]);
  if (client.call(service)) {
    ROS_INFO("Sum: %ld", (long int)service.response.sum);
  } else {
    ROS_ERROR("Failed to call service add_two_ints");
    return 1;
  }
  return 0;
}
```

ROS Actions (actionlib)

- Similar to service calls, but provide possibility to
 - Cancel the task (preempt)
 - Receive feedback on the progress
- Best way to implement interfaces to time-extended, goal-oriented behaviors
- Similar in structure to services, action are defined in **.action* files
- Internally, actions are implemented with a set of topics



More info

<http://wiki.ros.org/actionlib>

<http://wiki.ros.org/actionlib/DetailedDescription>

ROS Actions (actionlib)

Averaging.action

```
int32 samples
---
float32 mean
float32 std_dev
---
int32 sample
float32 data
float32 mean
float32 std_dev
```

Goal

Result

Feedback

FollowPath.action

```
navigation_msgs/Path path
---
bool success
---
float32 remaining_distance
float32 initial_distance
```

ROS Parameters, Dynamic Reconfigure, Topics, Services, and Actions Comparison

	Parameters	Dynamic Reconfigure	Topics	Services	Actions
Description	Global constant parameters	Local, changeable parameters	Continuous data streams	Blocking call for processing a request	Non-blocking, preemptable goal oriented tasks
Application	Constant settings	Tuning parameters	One-way continuous data flow	Short triggers or calculations	Task executions and robot actions
Examples	Topic names, camera settings, calibration data, robot setup	Controller parameters	Sensor data, robot state	Trigger change, request state, compute quantity	Navigation, grasping, motion execution

ROS Time

- Normally, ROS uses the PC's system clock as time source (*wall time*)
- For simulations or playback of logged data, it is convenient to work with a simulated time (pause, slow-down etc.)
- To work with a simulated clock:
 - Set the `/use_sim_time` parameter


```
> roseth param set use_sim_time true
```
 - Publish the time on the topic `/clock` from
 - Gazebo (enabled by default)
 - ROS bag (use option `--clock`)

- To take advantage of the simulated time, you should always use the ROS Time APIs:

- **ros::Time**

```
ros::Time begin = ros::Time::now();
double secs = begin.toSec();
```

- **ros::Duration**

```
ros::Duration duration(0.5); // 0.5s
```

- **ros::Rate**

```
ros::Rate rate(10); // 10Hz
```

- If wall time is required, use `ros::WallTime`, `ros::WallDuration`, and `ros::WallRate`

More info

<http://wiki.ros.org/Clock>

<http://wiki.ros.org/roscpp/Overview/Time>

ROS Bags

- A *bag* is a format for storing message data
- Binary format with file extension *.bag
- Suited for logging and recording datasets for later visualization and analysis

Record all topics in a bag

```
> rosbag record --all
```

Record given topics

```
> rosbag record topic_1 topic_2 topic_3
```

Stop recording with Ctrl + C

Bags are saved with start date and time as file name in the current folder (e.g. 2017-02-07-01-27-13.bag)

Show information about a bag

```
> rosbag info bag_name.bag
```

Read a bag and publish its contents

```
> rosbag play bag_name.bag
```

Playback options can be defined e.g.

```
> rosbag play --rate=0.5 bag_name.bag
```

<code>--rate=factor</code>	Publish rate factor
<code>--clock</code>	Publish the clock time (set param <code>use_sim_time</code> to true)
<code>--loop</code>	Loop playback etc.

More info

<http://wiki.ros.org/rosbag/Commandline>

Debugging Strategies

Debug with the tools you have learned

- Compile and run code often to catch bugs early
- Understand compilation and runtime error messages
- Use analysis tools to check data flow (rostopic info, rostopic echo, rosweb, rqt_graph etc.)
- Visualize and plot data (RViz, RQT Multiplot etc.)
- Divide program into smaller steps and check intermediate results (ROS_INFO, ROS_DEBUG etc.)
- Make your code robust with argument and return value checks and catch exceptions
- If things don't make sense, clean your workspace

```
> catkin clean --all
```

Learn new tools

- Build in *debug* mode and use GDB or Valgrind
- Use Eclipse breakpoints
- Maintain code with unit tests and integration tests

```
> catkin config --cmake-args  
-DCMAKE_BUILD_TYPE=Debug
```

More info

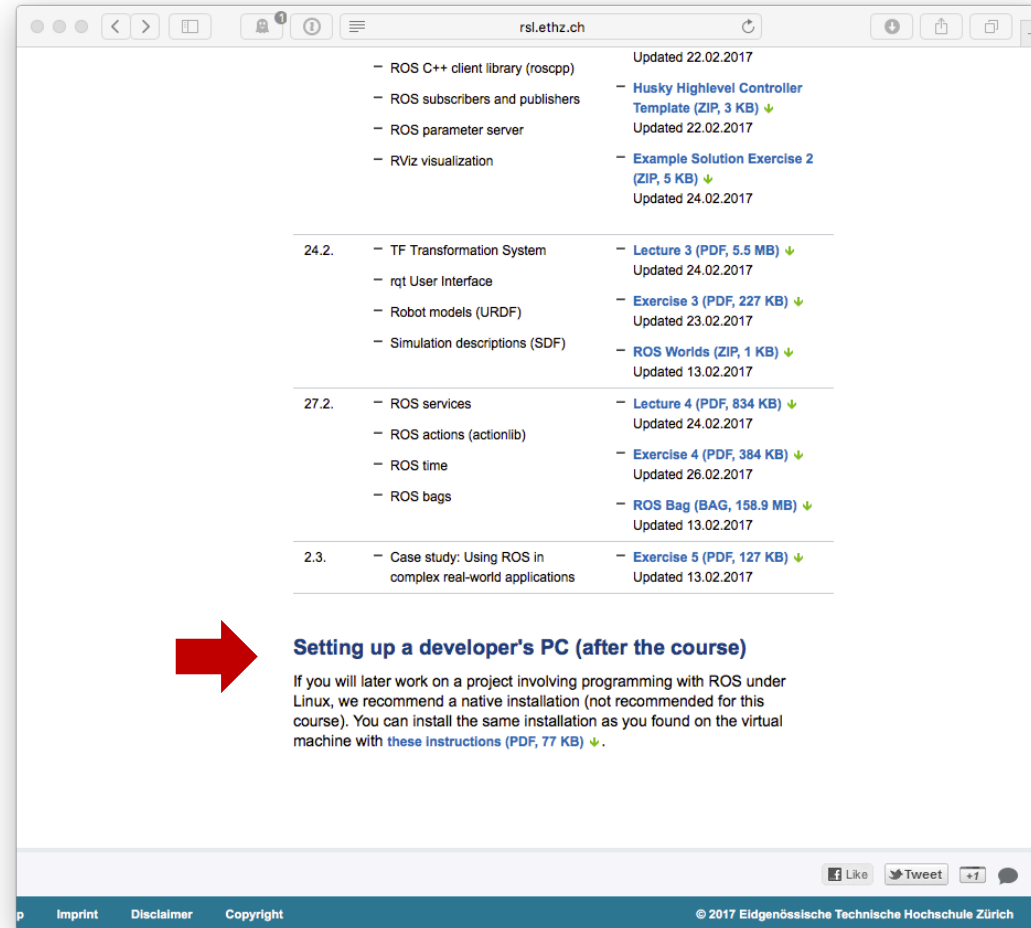
<http://wiki.ros.org/UnitTesting>

<http://wiki.ros.org/gtest>

<http://wiki.ros.org/roctest>

<http://wiki.ros.org/roslaunch/Tutorials/Roslaunch%20Nodes%20in%20Valgrind%20or%20GDB>

Setting Up up a Developer's PC



The screenshot shows a web browser window with the URL rsl.ethz.ch. The page displays a list of ROS-related resources, including client libraries, parameter servers, and visualization tools. A red arrow points to a section titled "Setting up a developer's PC (after the course)".

	- ROS C++ client library (roscpp)	Updated 22.02.2017
	- ROS subscribers and publishers	- Husky Highlevel Controller Template (ZIP, 3 KB) ↓
	- ROS parameter server	Updated 22.02.2017
	- RViz visualization	- Example Solution Exercise 2 (ZIP, 5 KB) ↓
		Updated 24.02.2017
24.2.	- TF Transformation System	- Lecture 3 (PDF, 5.5 MB) ↓
	- rqt User Interface	Updated 24.02.2017
	- Robot models (URDF)	- Exercise 3 (PDF, 227 KB) ↓
	- Simulation descriptions (SDF)	Updated 23.02.2017
		- ROS Worlds (ZIP, 1 KB) ↓
		Updated 13.02.2017
27.2.	- ROS services	- Lecture 4 (PDF, 834 KB) ↓
	- ROS actions (actionlib)	Updated 24.02.2017
	- ROS time	- Exercise 4 (PDF, 384 KB) ↓
	- ROS bags	Updated 26.02.2017
		- ROS Bag (BAG, 158.9 MB) ↓
		Updated 13.02.2017
2.3.	- Case study: Using ROS in complex real-world applications	- Exercise 5 (PDF, 127 KB) ↓
		Updated 13.02.2017

Setting up a developer's PC (after the course)

If you will later work on a project involving programming with ROS under Linux, we recommend a native installation (not recommended for this course). You can install the same installation as you found on the virtual machine with [these instructions \(PDF, 77 KB\)](#) ↓.

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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

Contact Information

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Course website:

<http://www.rsl.ethz.ch/education-students/lectures/ros.html>