rtt_lwr Documentation

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Installation and Configuration


ISIR
INSTITUT
DES SYSTÈMES
INTELLIGENTS
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CHAPTER 1

Introduction

rtt_lwr is a set of components for controlling the Kuka LWR and IIWA at 1Khz. It relies on OROCOS for the real-time part, but also interfaces with ROS such as Rviz, MoveIt, ros-control etc.

It has been designed so researchers/Phd Students/Engineers at ISIR can develop generic controllers for light weight robots and seemlessly test on simulation of the real robot without recompiling their code.

CHAPTER 2

Experimental setup

Installation on Ubuntu 14.04

ROS Indigo ++

From http://wiki.ros.org/indigo/Installation/Ubuntu.

Required tools

```
sudo sh -c "echo 'deb http://packages.ros.org/ros/ubuntu $(lsb_release -cs) main' > /
↪etc/apt/sources.list.d/ros-latest.list"
wget http://packages.ros.org/ros.key -O - | sudo apt-key add -
sudo apt update
sudo apt install python-rosdep python-catkin-tools ros-indigo-catkin python-wstool␣
↪python-vcstool
```

Fix Locales

```
sudo locale-gen en_US #warnings might occur
sudo locale-gen en_US.UTF-8
sudo nano /etc/environment
# put theses lines
LANGUAGE=en_US
LC_ALL=en_US
# Reboot !
```

If you type `perl` you should not see any warnings.

ROS Indigo Desktop

```
# ROS Desktop (NOT DESKTOP-FULL)
sudo apt install ros-indigo-desktop
```

> **Warning:** Do not install **desktop-full** (desktop + gazebo 2.2) as we'll use Gazebo 7.

After Install

```
# Load The environment
source /opt/ros/indigo/setup.bash
# Update ROSdep (to get dependencies automatically)
sudo rosdep init
rosdep update
```

MoveIt! (via debians)

```
# MoveIt!
sudo apt install ros-indigo-moveit
```

MoveIt! (from source)

If you need bleeing-edge features, compile MoveIt! from source :

```
mkdir -p ~/isir/moveit_ws/src
cd ~/isir/moveit_ws/src
# Get all the packages
wstool init
wstool merge https://raw.githubusercontent.com/ros-planning/moveit_docs/indigo-devel/
↪moveit.rosinstall
wstool update -j2
cd ~/isir/moveit_ws/
# Install dependencies
source /opt/ros/indigo/setup.bash
rosdep install --from-paths ~/isir/moveit_ws/src --ignore-src --rosdistro indigo -y -r
# Configure the workspace
catkin config --init --install --extend /opt/ros/indigo --cmake-args -DCMAKE_BUILD_
↪TYPE=Release
# Build
catkin build
```

OROCOS 2.9 + rtt_ros_integration 2.9 (from source)

If you already completed these instructions, and you are **upgrading from orocos 2.8** :

- If you installed orocos 2.8 from the debians, you need to remove them `sudo apt remote ros-kinetic-orocos-toolchain ros-kinetic-rtt-*`.
- If you installed orocos 2.8 from source, they can live side by side in a **different** workspace, but always check `catkin config` on your lwr_ws to make sure which workspace you are extending.

Additionally, please make sure that these repos (if you have them) are in the right branches (with fixes for rtt) :

```
roscd rtt_dot_service && git remote set-url origin https://github.com/kuka-isir/rtt_
↪dot_service.git && git pull
roscd fbsched && git remote set-url origin https://github.com/kuka-isir/fbsched.git &&
↪ git pull
roscd conman && git remote set-url origin https://github.com/kuka-isir/conman.git &&␣
↪git pull
```

OROCOS toolchain 2.9

```
mkdir -p ~/isir/orocos-2.9_ws/src
cd ~/isir/orocos-2.9_ws/src
# Get all the packages
wstool init
wstool merge https://raw.githubusercontent.com/kuka-isir/rtt_lwr/rtt_lwr-2.0/lwr_
↪utils/config/orocos_toolchain-2.9.rosinstall
wstool update -j2
# Get the latest updates (OPTIONAL)
cd orocos_toolchain
git submodule foreach git checkout toolchain-2.9
git submodule foreach git pull
# Configure the workspace
cd ~/isir/orocos-2.9_ws/
# Install dependencies
source /opt/ros/indigo/setup.bash
rosdep install --from-paths ~/isir/orocos-2.9_ws/src --ignore-src --rosdistro indigo -
↪y -r
catkin config --init --install --extend /opt/ros/indigo/ --cmake-args -DCMAKE_BUILD_
↪TYPE=Release
# Build
catkin build
```

rtt_ros_integration 2.9

```
mkdir -p ~/isir/rtt_ros-2.9_ws/src
cd ~/isir/rtt_ros-2.9_ws/src
# Get all the packages
wstool init
wstool merge https://github.com/kuka-isir/rtt_lwr/raw/rtt_lwr-2.0/lwr_utils/config/
↪rtt_ros_integration-2.9.rosinstall
wstool update -j2
# Configure the workspace
cd ~/isir/rtt_ros-2.9_ws/
# Install dependencies
source ~/isir/orocos-2.9_ws/install/setup.bash
rosdep install -q --from-paths ~/isir/rtt_ros-2.9_ws/src --ignore-src --rosdistro␣
↪indigo -y -r
catkin config --init --install --extend ~/isir/orocos-2.9_ws/install --cmake-args -
↪DCMAKE_BUILD_TYPE=Release
# Build (this can take a while)
catkin build
```

Use OROCOS with CORBA + MQUEUE (Advanced)

In order to use the corba interface (connect multiple deployers together), you'll need to build the orocos_ws and rtt_ros_ws with :

```
catkin config --cmake-args -DCMAKE_BUILD_TYPE=Release -DENABLE_MQ=ON -DENABLE_
↪CORBA=ON -DCORBA_IMPLEMENTATION=OMNIORB
```

Reference : http://www.orocos.org/stable/documentation/rtt/v2.x/doc-xml/orocos-components-manual.html#orocos-corba

Gazebo 7

From http://gazebosim.org/tutorials?tut=install_ubuntu&cat=install.

Note: If you already have gazebo 2.2 installed, please remove it : *sudo apt remove gazebo libgazebo-dev ros-indigo-gazebo-**

```
# Gazebo 7
curl -ssL http://get.gazebosim.org | sh
# The ros packages
sudo apt install ros-indigo-gazebo7-*
```

Note: Don't forget to put source `source /usr/share/gazebo/setup.sh` in your `~/isir/.bashrc` or you won't have access to the gazebo plugins (Simulated cameras, lasers, etc).

ROS Control

This allows you to use MoveIt! or just the ros_control capabilities in an orocos environnement. Let's install everything :

```
sudo apt install ros-indigo-ros-control* ros-indigo-control*
```

RTT LWR packages

```
mkdir -p ~/isir/lwr_ws/src/
cd ~/isir/lwr_ws/src
# Get all the packages
wstool init
# Get rtt_lwr 'base'
wstool merge https://raw.githubusercontent.com/kuka-isir/rtt_lwr/rtt_lwr-2.0/lwr_
↪utils/config/rtt_lwr.rosinstall
# Get the extra packages
wstool merge https://raw.githubusercontent.com/kuka-isir/rtt_lwr/rtt_lwr-2.0/lwr_
↪utils/config/rtt_lwr-extras.rosinstall

# Download
wstool update -j2
```

Note: If you want to install and test cart_opt_ctrl : `wstool merge https://raw.githubusercontent.com/kuka-isir/rtt_lwr/rtt_lwr-2.0/lwr_utils/config/rtt_lwr-full.rosinstall`

Install dependencies

```
source ~/isir/rtt_ros-2.9_ws/install/setup.bash
rosdep install --from-paths ~/isir/lwr_ws/src --ignore-src --rosdistro indigo -y -r
```

Note: On **indigo**, rosdep will try to install **gazebo 2**, but will fail as we already installed **gazebo 7**. So you can **ignore** this error if you are running indigo. On ROS kinetic, it will install gazebo7 automatically.

```
executing command [sudo -H apt-get install gazebo2]
Reading package lists... Done
Building dependency tree
Reading state information... Done
Some packages could not be installed. This may mean that you have
requested an impossible situation or if you are using the unstable
distribution that some required packages have not yet been created
or been moved out of Incoming.
The following information may help to resolve the situation:

The following packages have unmet dependencies:
 gazebo2 : Depends: libsdformat-dev (>= 1.4.11-1osrf1) but it is not going to be installed
           Depends: libsdformat-dev (< 2.0.0) but it is not going to be installed
E: Unable to correct problems, you have held broken packages.
ERROR: the following rosdeps failed to install
  apt: command [sudo -H apt-get install gazebo2] failed
  apt: Failed to detect successful installation of [gazebo2]
```

Configure the workspace

```
cd ~/isir/lwr_ws
catkin config --init --extend ~/isir/rtt_ros-2.9_ws/install --cmake-args -DCMAKE_
↪BUILD_TYPE=Release
```

Build the workspace

Let's build the entire workspace :

```
catkin build --worspace ~/isir/lwr_ws
```

```
Starting  >>> rtt_gazebo_embedded
Finished  <<< lwr_project_creator                [ 0.5 seconds ]
Finished  <<< ros_recorder                       [ 0.4 seconds ]
Finished  <<< lwr_ikfast                         [ 0.8 seconds ]
Finished  <<< polaris_sensor                     [ 0.7 seconds ]
Finished  <<< rtt_dot_service                    [ 0.2 seconds ]
Finished  <<< rtt_gazebo_embedded                [ 0.2 seconds ]
Starting  >>> rtt_ros_control_embedded
Starting  >>> rtt_ros_kdl_tools
Starting  >>> trac_ik_lib
Finished  <<< rtt_controller_manager_msgs        [ 0.7 seconds ]
Starting  >>> rtt_ros_control_node
Starting  >>> lwr_fri
Starting  >>> lwr_moveit_config
Starting  >>> lwr_utils
Finished  <<< rtt_control_msgs                   [ 1.3 seconds ]
Starting  >>> rtt_ati_sensor
Finished  <<< lwr_moveit_config                  [ 0.3 seconds ]
Finished  <<< trac_ik_lib                        [ 0.7 seconds ]
```

Once it's done, load the workspace :

```
source ~/isir/lwr_ws/devel/setup.bash
```

Tip: Put it in you bashrc : `echo 'source ~/isir/lwr_ws/devel/setup.bash' >> ~/.bashrc`

Now we can *test the installation*.

Installation on Ubuntu 16.04

ROS Kinetic ++

From http://wiki.ros.org/kinetic/Installation/Ubuntu.

Required tools

```
sudo sh -c "echo 'deb http://packages.ros.org/ros/ubuntu $(lsb_release -cs) main' > /
↪etc/apt/sources.list.d/ros-latest.list"
wget http://packages.ros.org/ros.key -O - | sudo apt-key add -
sudo apt update
sudo apt install python-rosdep python-catkin-tools ros-kinetic-catkin python-wstool␣
↪python-vcstool
```

Fix Locales

```
sudo locale-gen en_US #warnings might occur
sudo locale-gen en_US.UTF-8
sudo nano /etc/environment
# put theses lines
LANGUAGE=en_US
LC_ALL=en_US
# Reboot !
```

If you type `perl` you should not see any warnings.

ROS Kinetic Desktop

```
# ROS Desktop (NOT DESKTOP-FULL)
sudo apt install ros-kinetic-desktop
```

After Install

```
# Load The environment
source /opt/ros/kinetic/setup.bash
# Update ROSdep (to get dependencies automatically)
sudo rosdep init
rosdep update
```

MoveIt! (via debians)

```
# MoveIt!
sudo apt install ros-kinetic-moveit
```

OROCOS 2.9 + rtt_ros_integration 2.9 (from source)

OROCOS toolchain 2.9

```
mkdir -p ~/isir/orocos-2.9_ws/src
cd ~/isir/orocos-2.9_ws/src
# Get all the packages
wstool init
wstool merge https://raw.githubusercontent.com/kuka-isir/rtt_lwr/rtt_lwr-2.0/lwr_
↪utils/config/orocos_toolchain-2.9.rosinstall
wstool update -j2
# Get the latest updates (OPTIONAL)
cd orocos_toolchain
git submodule foreach git checkout toolchain-2.9
git submodule foreach git pull
# Configure the workspace
cd ~/isir/orocos-2.9_ws/
# Install dependencies
source /opt/ros/kinetic/setup.bash
rosdep install --from-paths ~/isir/orocos-2.9_ws/src --ignore-src --rosdistro kinetic␣
↪-y -r
catkin config --init --install --extend /opt/ros/kinetic/ --cmake-args -DCMAKE_BUILD_
↪TYPE=Release
```

```
# Build
catkin build
```

rtt_ros_integration 2.9

```
mkdir -p ~/isir/rtt_ros-2.9_ws/src
cd ~/isir/rtt_ros-2.9_ws/src
# Get all the packages
wstool init
wstool merge https://github.com/kuka-isir/rtt_lwr/raw/rtt_lwr-2.0/lwr_utils/config/
↪rtt_ros_integration-2.9.rosinstall
wstool update -j2
# Configure the workspace
cd ~/isir/rtt_ros-2.9_ws/
# Install dependencies
source ~/isir/orocos-2.9_ws/install/setup.bash
rosdep install --from-paths ~/isir/rtt_ros-2.9_ws/src --ignore-src --rosdistro␣
↪kinetic -y -r
catkin config --init --install --extend ~/isir/orocos-2.9_ws/install --cmake-args -
↪DCMAKE_BUILD_TYPE=Release
# Build (this can take a while)
catkin build
```

Use OROCOS with CORBA + MQUEUE (Advanced)

In order to use the corba interface (connect multiple deployers together), you'll need to build the orocos_ws and rtt_ros_ws with :

```
catkin config --cmake-args -DCMAKE_BUILD_TYPE=Release -DENABLE_MQ=ON -DENABLE_
↪CORBA=ON -DCORBA_IMPLEMENTATION=OMNIORB
```

Reference : http://www.orocos.org/stable/documentation/rtt/v2.x/doc-xml/orocos-components-manual.html#orocos-corba

Gazebo 8

From http://gazebosim.org/tutorials?tut=install_ubuntu&cat=install.

```
# Gazebo 8
curl -ssL http://get.gazebosim.org | sh
# The ros packages
sudo apt install ros-kinetic-gazebo8-*
```

Note: Don't forget to put source `source /usr/share/gazebo/setup.sh` in your `~/isir/.bashrc` or you won't have access to the gazebo plugins (Simulated cameras, lasers, etc).

ROS Control

This allows you to use MoveIt! or just the ros_control capabilities in an orocos environnement. Let's install everything :

```
sudo apt install ros-kinetic-ros-control* ros-kinetic-control*
```

RTT LWR packages

```
mkdir -p ~/isir/lwr_ws/src/
cd ~/isir/lwr_ws/src
# Get all the packages
wstool init
# Get rtt_lwr 'base'
wstool merge https://raw.githubusercontent.com/kuka-isir/rtt_lwr/rtt_lwr-2.0/lwr_
↪utils/config/rtt_lwr.rosinstall
# Get the extra packages
wstool merge https://raw.githubusercontent.com/kuka-isir/rtt_lwr/rtt_lwr-2.0/lwr_
↪utils/config/rtt_lwr-extras.rosinstall

# Download
wstool update -j2
```

Note: If you want to install and test cart_opt_ctrl : `wstool merge https://raw.githubusercontent.com/kuka-isir/rtt_lwr/rtt_lwr-2.0/lwr_utils/config/rtt_lwr-full.rosinstall`

Install dependencies

```
# If you compiled rtt_ros from sources
source ~/isir/rtt_ros-2.9_ws/install/setup.bash
# Use rosdep tool
rosdep install --from-paths ~/isir/lwr_ws/src --ignore-src --rosdistro kinetic -y -r
```

Note: Gazebo 7 is shipped by default with kinetic, so rosdep will try to install it and fail. You can ignore this issue safely as you now have Gazebo 8 installed.

Configure the workspace

If building rtt_ros **from source** :

```
cd ~/isir/lwr_ws
catkin config --init --extend ~/isir/rtt_ros-2.9_ws/install --cmake-args -DCMAKE_CXX_
↪FLAGS=-std=c++11 -DCMAKE_BUILD_TYPE=Release
```

Build the workspace

Let's build the entire workspace :

```
catkin build --workspace ~/isir/lwr_ws
```

```
Starting  >>> rtt_gazebo_embedded
Finished  <<< lwr_project_creator                [ 0.5 seconds ]
Finished  <<< ros_recorder                       [ 0.4 seconds ]
Finished  <<< lwr_ikfast                         [ 0.8 seconds ]
Finished  <<< polaris_sensor                     [ 0.7 seconds ]
Finished  <<< rtt_dot_service                    [ 0.2 seconds ]
Finished  <<< rtt_gazebo_embedded                [ 0.2 seconds ]
Starting  >>> rtt_ros_control_embedded
Starting  >>> rtt_ros_kdl_tools
Starting  >>> trac_ik_lib
Finished  <<< rtt_controller_manager_msgs        [ 0.7 seconds ]
Starting  >>> rtt_ros_control_node
Starting  >>> lwr_fri
Starting  >>> lwr_moveit_config
Starting  >>> lwr_utils
Finished  <<< rtt_control_msgs                   [ 1.3 seconds ]
Starting  >>> rtt_ati_sensor
Finished  <<< lwr_moveit_config                  [ 0.3 seconds ]
Finished  <<< trac_ik_lib                        [ 0.7 seconds ]
```

Once it's done, load the workspace :

```
source ~/isir/lwr_ws/devel/setup.bash
```

Tip: Put it in you bashrc : `echo 'source ~/isir/lwr_ws/devel/setup.bash' >> ~/.bashrc`

Now we can *test the installation*.

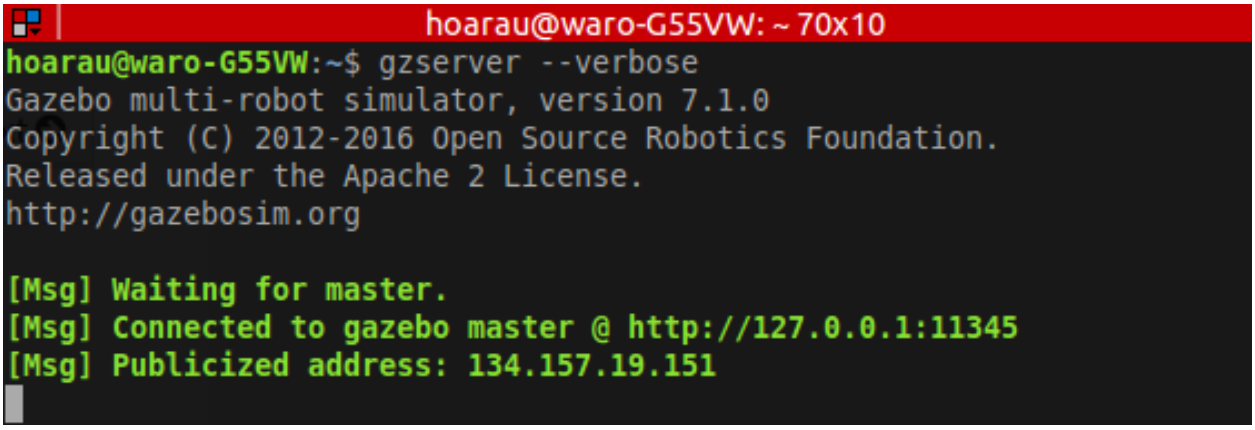
Test your installation

We're gonna test every components to make sure everything is working correctly.

Gazebo

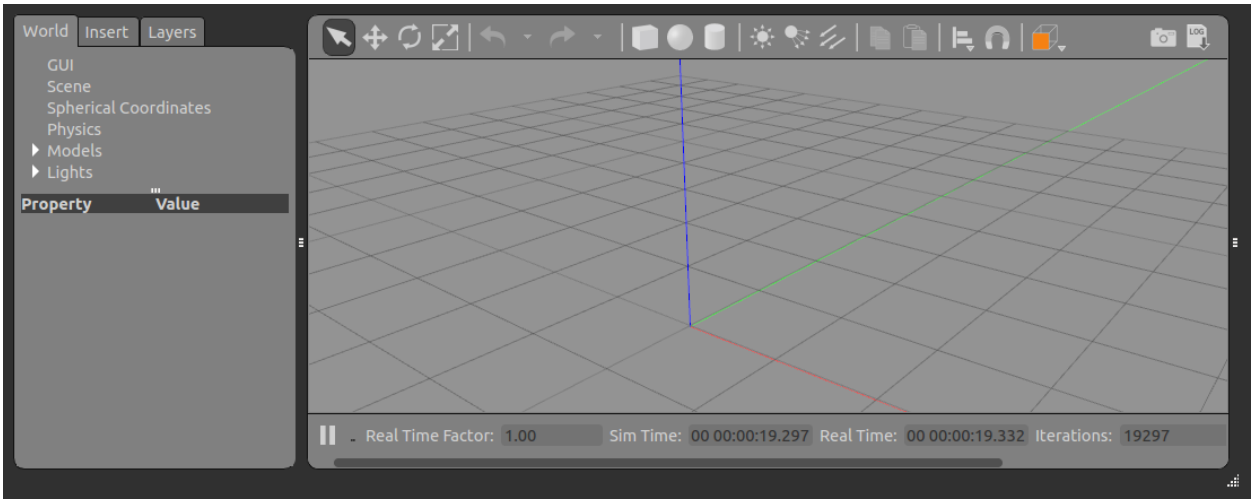
Gazebo needs to get some models at the first launch, so in a terminal type :

```
gzserver --verbose
```



Then `ctrl+C` to close it and type :

```
gazebo
```



Gazebo-ROS

Gazebo with ROS plugin

Start the roscore : `roscore`

Close any instance of gazebo running, and then launch gazebo with the ros plugins :

```
gazebo -s libgazebo_ros_paths_plugin.so -s libgazebo_ros_api_plugin.so --verbose
```

Upload the robot's URDF

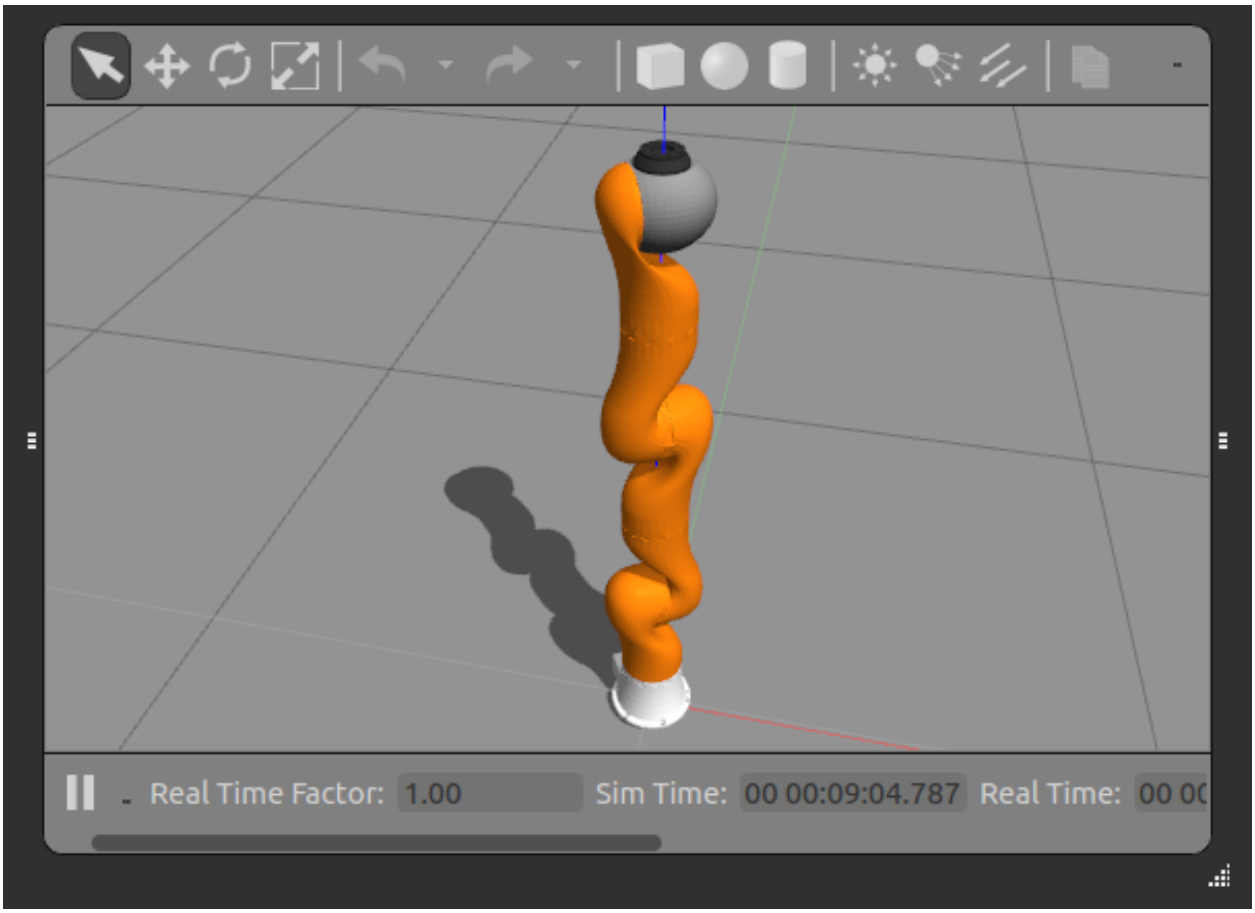
```
roslaunch lwr_description lwr_upload.launch
# you can also pass load_ati_sensor:=true load_handle:=true load_base:=true
```

Note: If the ROS API is loaded correctly, this command should exit immediately

Spawn to robot into Gazebo

```
roslaunch lwr_utils spawn_robot.launch robot_name:=lwr_sim
```

Note: If the model has been correctly uploaded, this command should also exit immediately



Test the rtt_lwr tools

Warning: **Close** all previous nodes, deployers, windows etc, and start the main deployer with gazebo.

Now gazebo is launched **inside** the orocos deployer !

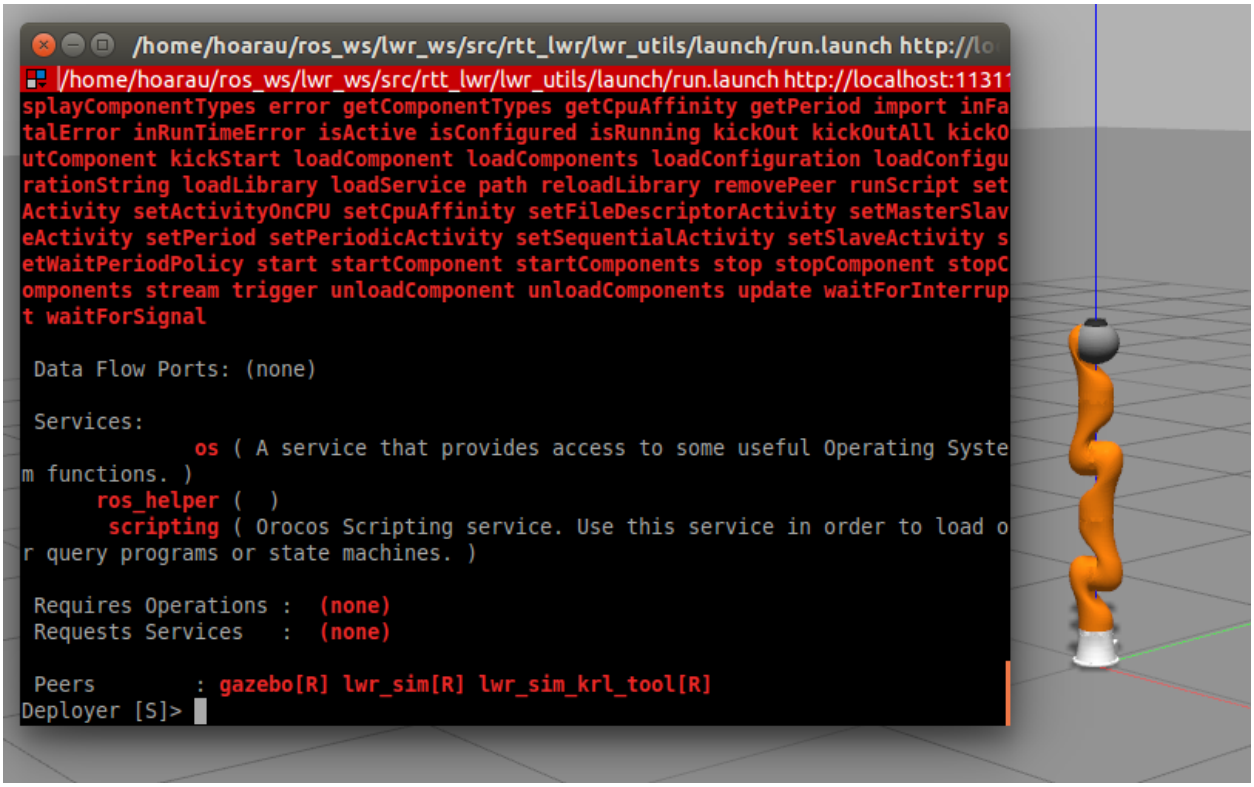
```
roslaunch lwr_utils run.launch sim:=true
```

Note: You can see the robot in the gazebi gui because the model is spawned into gazebo via the main launch file. Still, it has no interface to send commands, what we'll do in the next step.

Now type :

```
# Load the lwr interface in the deployer
loadRobot(getRobotName(), isSim(), true)
# Let it load, then print the components :
ls
```

You should see all the components `running [R]` :



Warning: The Gazebo server is launched **inside** the `gazebo` component (that you can see if you type `ls`). You **will not** be able to launch gazebo separately, it has to be instanciated inside the orocos deployer via this method. This component is provided by the https://github.com/kuka-isir/rtt_gazebo_embedded package.

Orocos tutorial

Orocos Basics

First, make you have the lwr workspace loaded `source ~/isir/lwr_ws/devel/setup.bash`

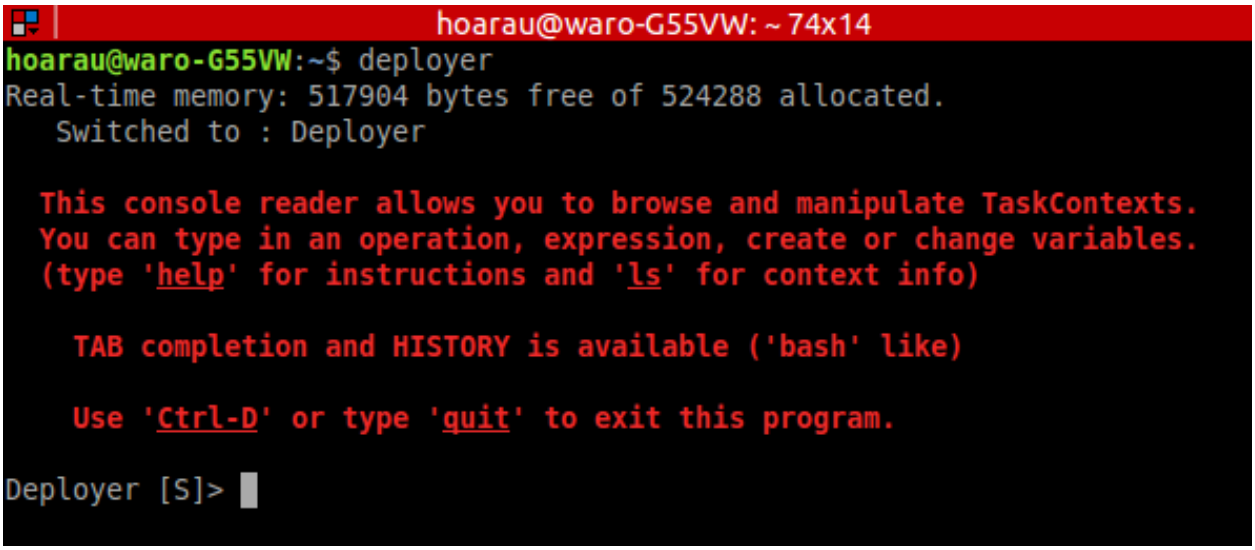
Note: Put this source file in your .bashrc : `echo `source ~/isir/lwr_ws/devel/setup.bash` >> ~/.bashrc`

Official documentation about the Orocos RealTime Toolkit (RTT) can be found here : http://www.orocos.org/stable/documentation/rtt/v2.x/doc-xml/orocos-components-manual.html

> The [orocos] Toolchain allows setup, distribution and the building of real-time software components. It is sometimes refered to as 'middleware' because it sits between the application and the Operating System. It takes care of the real-time communication and execution of software components.

All components are 'deployed' using a single executable called the 'deployer'. The main deployer has the ability to load component, connect them to exchange data, start, stop, change their rate etc. To launch it just type in a terminal :

```
deployer
```



Example of a simple 2 components deployement :

```
# Let's load a built-in orocos component
loadComponent("hello","OCL::HelloWorld") # calls the constructor
# If you want to see its ports, properties, attribues :
ls hello
# You can see :
# Data Flow Ports:
# Out(U)      string the_results    =>
#  In(U)      string the_buffer_port <= ( use 'the_buffer_port.read(sample)'
# to read a sample from this port)
# It means it has 1 input port and 1 output port
#
# We'll build another component of the same type
loadComponent("hello2","OCL::HelloWorld")

# Let's connect their interface
# It's a bi-laterial connection that allow hello1 to connect with hello2's
# ports, attributes etc, and also hello2 to get data from hello
connectPeers("hello","hello2")

# Connect ports
connect("hello.the_buffer_port","hello2.the_results",ConnPolicy())
```

```
# The last argument ConnPolicy() is a structure that contains the way
# to send data from one component to another. Default is "DATA"

# Let's run everything

# Setting the activity of
# "hello"
# to a period of 0.1 seconds (10Hz)
# with the thread priority of 10 (0..99)
# It's a standard linux thread
setActivity("hello",0.1,10,ORO_SCHED_OTHER)

setActivity("hello2",0.2,25,ORO_SCHED_OTHER)

# call configureHook()
hello.configure() #  registered as an 'operation' called 'configure'
 # call updateHook()
hello.start()

hello2.configure()
hello2.start()

# Note that parenthesis are not required for void arguments

# Let's see the data :

hello.the_buffer_port.last
# It will show
# "Hello World !"
```

Tip: Open a `deployer` and copy/paste the lines one by one to test.

For further documentation, please refer to the Orocos Builder's Manual.

Orocos - ROS bridge

All the magic is done by rtt_ros_integration https://github.com/orocos/rtt_ros_integration. Basically every ROS function that you might be used to call in regular rosnode has been wrapped for orocos to be Real-Time Safe.

Most used features :

- Transform the deployer into a ROS node (rtt_rosnode)
- Connect an Orocos port to a ROS topic (rtt_roscomm)
- Connect an Orocos operation to a ROS service (rtt_roscomm)
- Map Orocos Parameters with the ROS parameter server (rtt_rosparam)

- Get the clock from ros (rtt_rosclock)

Custom Orocos Components with Catkin

Now let's build our own Orocos Component (Very simple one with no ports, operation nor properties) :

```
#include <rtt/RTT.hpp>
#include <rtt/TaskContext.hpp>
#include <rtt/Component.hpp>
#include <rtt/Logger.hpp>

class MyComponent : public RTT::TaskContext
{
   // Constructor
   // That's the name you're gonna pass as first argument of "loadComponent"
   MyComponent(const std::string& name):
   RTT::TaskContext(name)
   {
        RTT::log(RTT::Info) << "Constructing ! " << RTT::endlog();
   }

   // The function called when writing my_component.configure()
   void configureHook()
   {
        RTT::log(RTT::Info) << "Configuring  ! " << RTT::endlog();
   }

   // The function called (periodically or not) when calling my_component.start()
   void updateHook()
   {
        RTT::log(RTT::Info) << "Updating ! " << RTT::endlog();
   }
};
ORO_CREATE_COMPONENT(MyComponent) //Let Orocos know how to build this component
```

The `CmakeLists.txt` can look like this :

```
cmake_minimum_required(VERSION 2.8.3)
project(my_component)

find_package(catkin REQUIRED COMPONENTS
    # This will automatically import all Orocos components in package.xml,
    # and put them in ${USE_OROCOS_LIBRARIES}
    rtt_ros
    cmake_modules
)

include_directories(
    #include
    ${USE_OROCOS_INCLUDE_DIRS}
    ${CATKIN_INCLUDE_DIRS}
)

orocos_component(my_component MyComponent.cpp)
set_property(TARGET my_component APPEND
        PROPERTY COMPILE_DEFINITIONS RTT_COMPONENT)
```

```
target_link_libraries(my_component
    ${USE_OROCOS_LIBRARIES}
    ${catkin_LIBRARIES}
)
# orocos_install_headers(DIRECTORY include/${PROJECT_NAME})
orocos_generate_package(INCLUDE_DIRS include)
```

Then you can just call `cd my_component; mkdir build ; cd build ; cmake .. && make`. This will generate in the build directory what you can expect from a ROS package : a **devel/** directory containing all the targets (here "my_component") and a **setup.bash**.

Note: Using a catkin workspace makes life much easier : you can put all your packages in `src/`, build them all at once, and you'll have the `setup.bash` at `my_ws/devel/setup.bash`

Now if you `source devel/setup.bash` and then call `deployer` , Orocos will know MyComponent in its environnement :

```
getComponentTypes() # You will see MyComponent !

loadComponent("my_component","MyComponent")
my_component.configure()
my_component.start()
```

Using `rtt_ros_integration` you can also call :

```
import("rtt_rospack")
ros.find("my_component")
```

Orocos documentation for building components : http://www.orocos.org/wiki/orocos/toolchain/getting-started/cmake-and-building

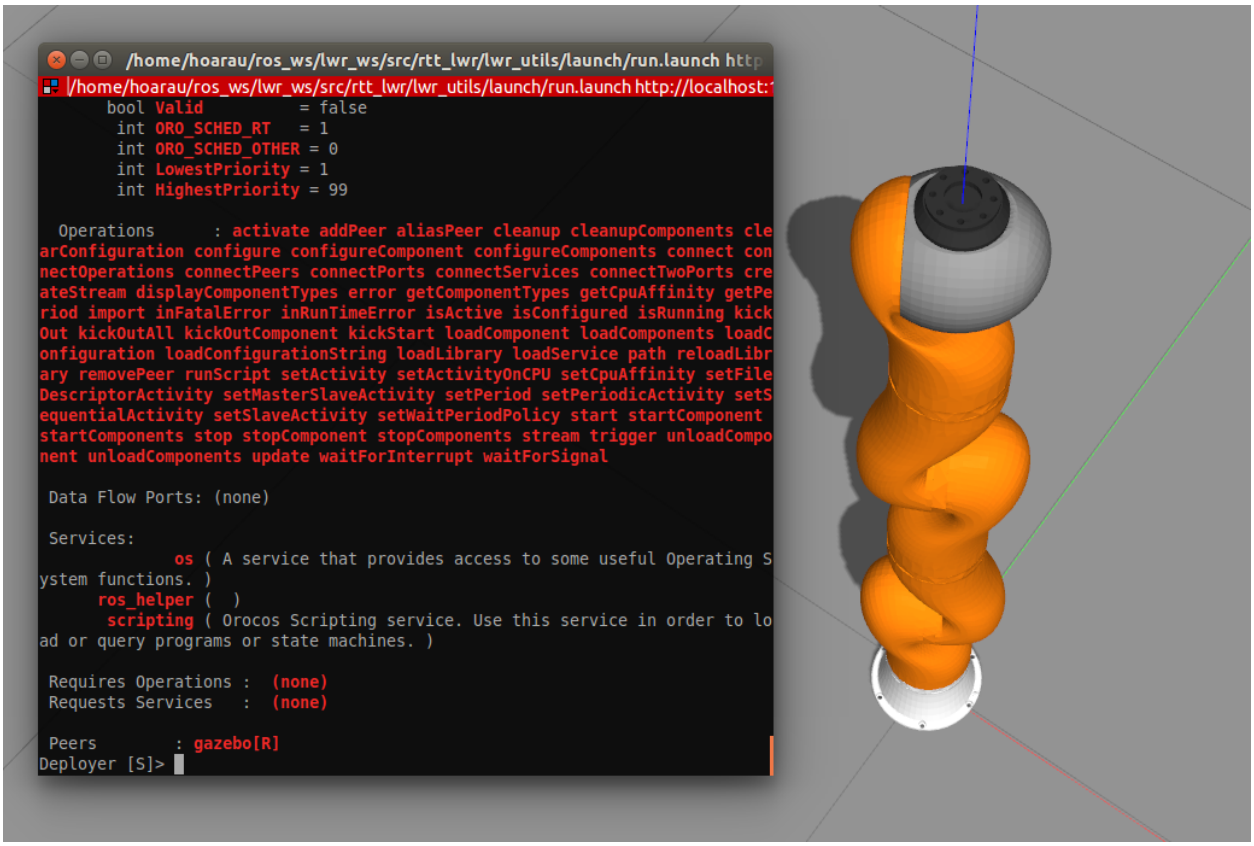
Orocos/ROS documentation for building components easily with catkin : https://github.com/orocos/rtt_ros_integration

Getting started with rtt_lwr 2.0

The main launch file

In lwr_utils, you'll find the main roslaunch to deploy the components :

```
roslaunch lwr_utils run.launch sim:=true
```



This uploads the `robot description` (tools accessible via `load_*:=true` arguments), the `robot_state_publisher` (the `joint_state_publisher` is done by an orocos component called `rtt_state_publisher`), the service to spawn the robot on gazebo and a few parameters to get the robot name, namespace, tf_prefix etc.

By default, this passes the **utils.ops script** that contains a bunch of useful functions to load the robot and a few components that comes with rtt_lwr. This script is located at `$(rospack find lwr_utils)/scripts/utils.ops`. You can change the script loaded by `run.launch` via the **ops_script:=** argument.

Later on, you're gonna pass your own customized script as argument : `touch my_script.ops && nano my_script.ops` and `run.launch ops_script:=/path/to/my_script.ops`

```
import("rtt_rospack")
runScript(ros.find("lwr_utils") + "/scripts/utils.ops")

# loadRobot(getRobotName(),isSim(),true)
# ....
# Your own functions !
```

Writing your own deployment script (ops file)

A typical sequence for deploying components would be :

```
# Load rospack to find packages in the ros workspace
import("rtt_rospack")
# Load the utility script into the deployer
runScript(ros.find("lwr_utils")+"/scripts/utils.ops")
# Load the robot
```

```
loadRobot(getRobotName(),isSim(),true)
# Load the state publisher for rviz visualization
loadStatePublisher(true)

# Then you can load your component, connect it etc.
```

Note: Instead of creating everything **by hand**, please follow the Controller Tutorial and generate a sample project.

Available global functions :

```
curl --silent https://raw.githubusercontent.com/kuka-isir/rtt_lwr/rtt_lwr-2.0/lwr_
↪utils/scripts/utils.ops | grep  global
```

```
global string getRobotName()
global string getRobotNs()
global string getTfPrefix()
global bool isSim()
global bool setRobotInitialJointConfiguration(double q0,double q1,double q2,double q3,
↪double q4,double q5,double q6)
global string loadKRLTool(bool start_component)
global void setJointTorqueControlMode()
global void setCartesianImpedanceControlMode()
global void setJointImpedanceControlMode()
global bool importRequiredPackages()
global bool connectPortsFromList(string controller_name,string robot_name,strings␣
↪ports_list ,ConnPolicy cp)
global bool connectStandardPorts(string controller_name,string robot_name, ConnPolicy␣
↪cp)
global bool connectLWRPorts(string controller_name,string robot_name, ConnPolicy cp)
global bool connectAllPorts(string controller_name,string robot_name, ConnPolicy cp)
global string loadStatePublisher(bool start_component)
global string loadConman()
global bool addComponentToStateEstimation(string component_name)
global bool addRobotToConman(string component_name)
global bool addControllerToConman(string component_name)
global string loadFBSched()
global bool addControllerToFBSched(string component_name)
global void generateGraph()
global string loadJointTrajectoryGeneratorKDL(bool start_component)
global string loadROSControl(bool start_component)
global string getAtiFTSensorDataPort()
global bool connectToAtiFTSensorPort(string comp_name,string port_name,ConnPolicy cp)
global string loadAtiFTSensor(bool start_component)
global string loadRobot(string robot_name,bool is_sim,bool start_component)
```

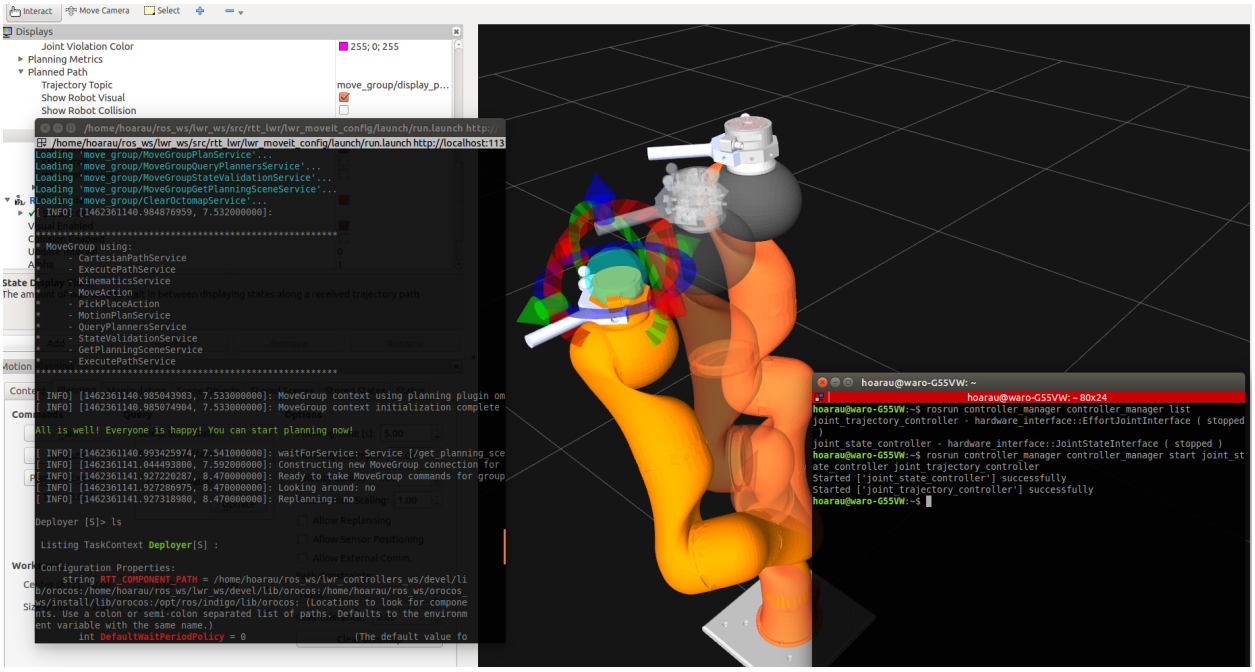
MoveIt! with rtt_ros_control_embedded

As the other packages, we'll use the `run.launch` from `lwr_utils` that we duplicated in the `lwr_moveit_config` package for custom arguments.

```
roslaunch lwr_moveit_config run.launch sim:=true
```

Then you can list available ros_control controllers :

```
rosrun controller_manager controller_manager list
```



Note: These commands launch the following RTT Components :

```
o gazebo
o lwr_sim
o rtt_ros_control_embedded
    --> controller_manager
    --> hardware interface
```

Then you have access to the full `ros_control` interface as a normal ROS module, so you can create you own ros_controllers. http://wiki.ros.org/ros_control.

Create your first OROCOS controller

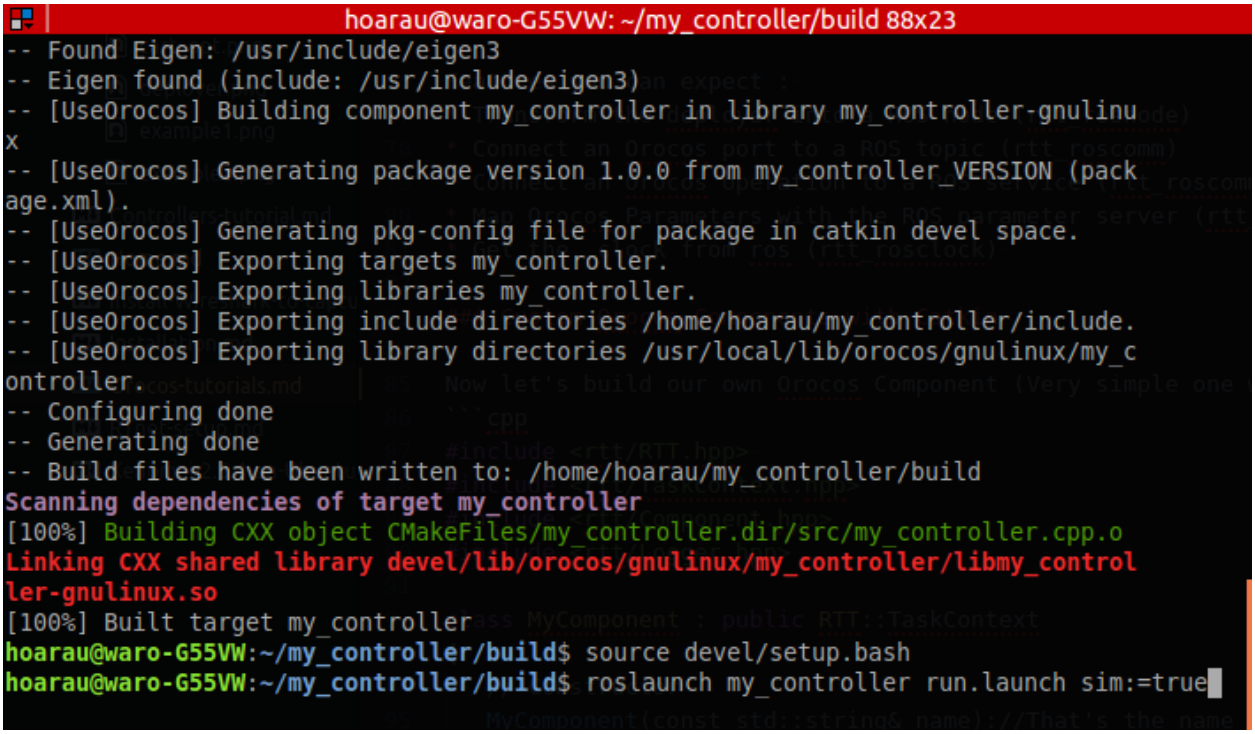
Using `lwr_create_pkg`

Using the lwr_project_creator utility, we can generate a (very) simple controller for our robot.

Generate the controller

```
mkdir -p ~/catkin_ws/src
cd ~/catkin_ws/src
lwr_create_pkg my_controller -C MyController

cd ~/catkin_ws
catkin config --init --extend ~/isir/lwr_ws/devel
```

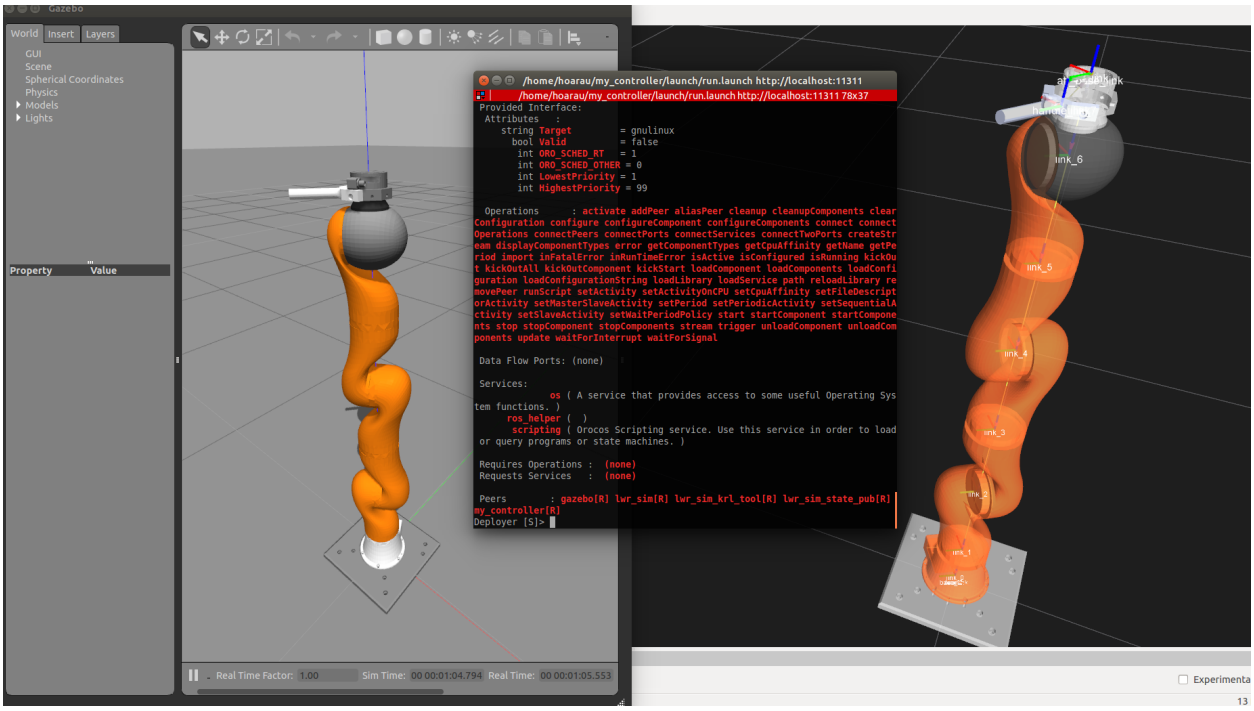
Build the controller




```
cd ~/catkin_ws
catkin build
# add the controller to the ros package path
source ~/catkin_ws/devel/setup.bash
```

Launch it :

```
roslaunch my_controller run.launch sim:=true
```



General note on controllers

This generated controller is "kuka-lwr-free" and as a general rule you should avoid to include kuka-lwr stuff in your code.

You should just see the robot as an ***Effort interface***,i.e, you should only listen to the current state (q,qdot) and publish torques.

Recommended ports are :

```
Robot input / Controller output:   - JointTorqueCommand
                                   - (JointPositionCommand)

Robot Output / Controller intput:  - JointPosition
                                   - JointVelocity
                                   - (JointTorque)
```

The complete list of LWR ports :

```
curl --silent https://raw.githubusercontent.com/kuka-isir/lwr_hardware/master/lwr_fri/
↪src/FRIComponent.cpp  | grep -oP 'addPort\( *\"\K\w+'
```

```
CartesianImpedanceCommand
CartesianWrenchCommand
CartesianPositionCommand
JointImpedanceCommand
JointPositionCommand
JointTorqueCommand          --> To Controller
toKRL                       --> KRL Tool
KRL_CMD                     --> KRL Tool
fromKRL                     --> KRL Tool
CartesianWrench
```

```
RobotState                  --> KRL Tool
FRIState                    --> KRL Tool
JointVelocity               --> To Controller
CartesianVelocity
CartesianPosition
MassMatrix
Jacobian
JointTorque                 --> To Controller
JointTorqueAct
GravityTorque
JointPosition               --> To Controller
JointPositionFRIOffset
```

The controller uses rtt_ros_kdl_tools::ChainUtils to create an "arm" object. This arm loads the robot_description from the ROS parameter server (you can use the provided launch file that helps you start everything), then create a few KDL chain, solvers etc to compute forward kinematics, jacobians etc.

Functions available can be found here.

Inverse Kinematics is included in ChainUtils via Trac IK .

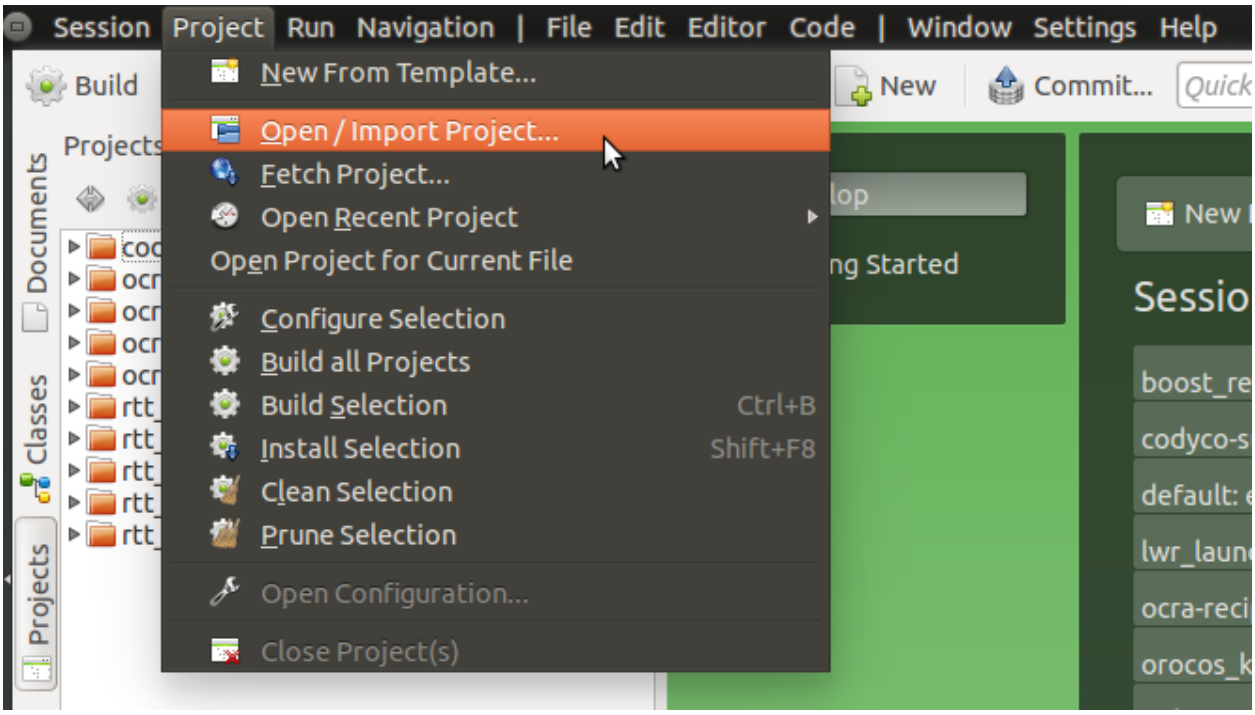
Make you life easier with Kdevelop

Kdevelop is a nice IDE that supports cmake natively. To install it, just type `sudo apt install kdevelop`, then in a **terminal**, type `kdevelop`.

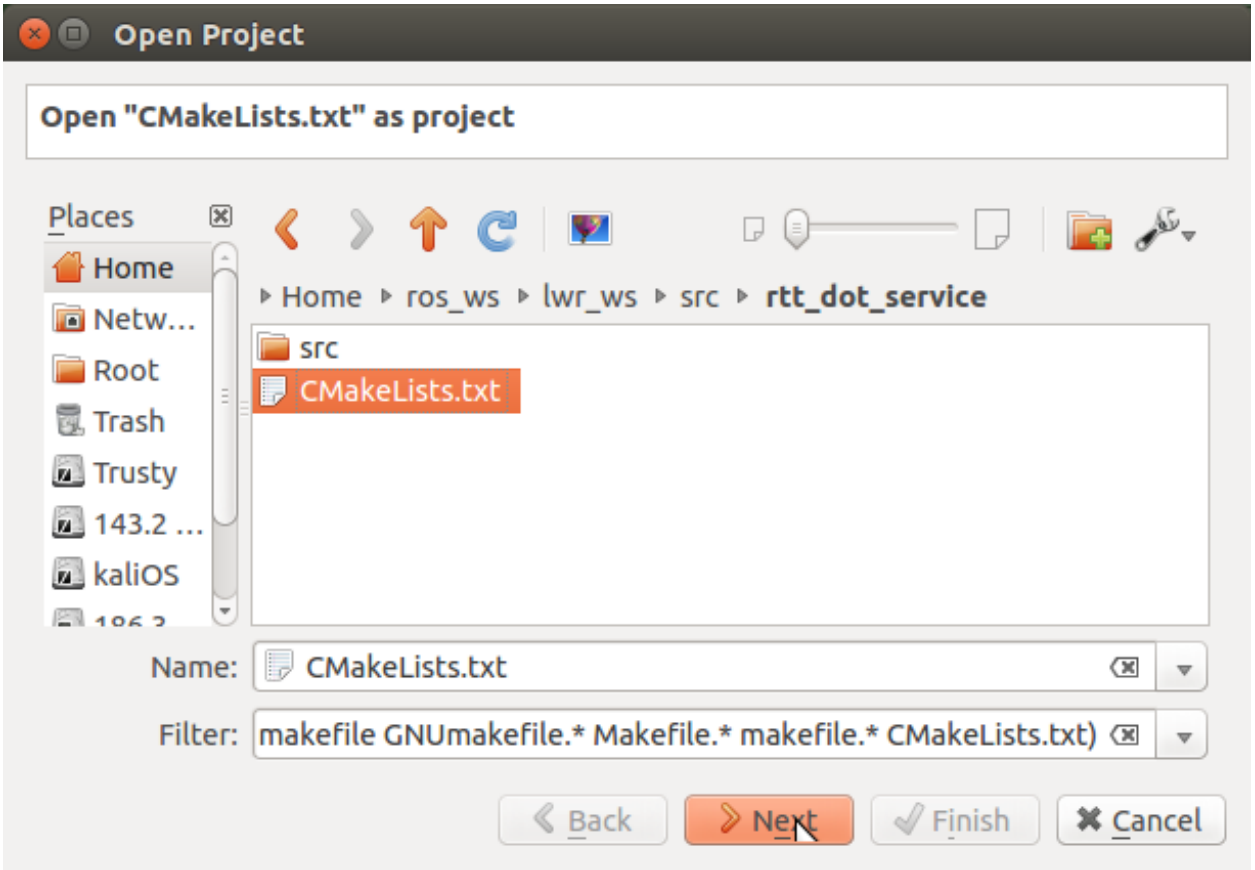
Tip: To enable sourcing the bashrc from the Ubuntu toolbar, `sudo nano /usr/share/applications/kde4/kdevelop.desktop` and replace `Exec=kdevelop %u` by `Exec=bash -i -c kdevelop %u`.

Import a catkin/CMake project

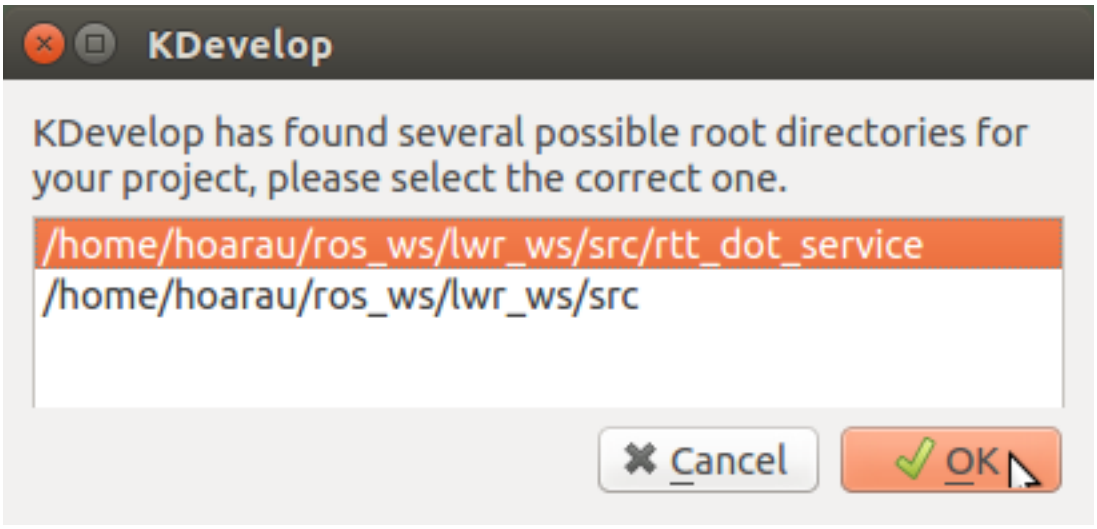
Click on `Project --> Open/Import Project...`



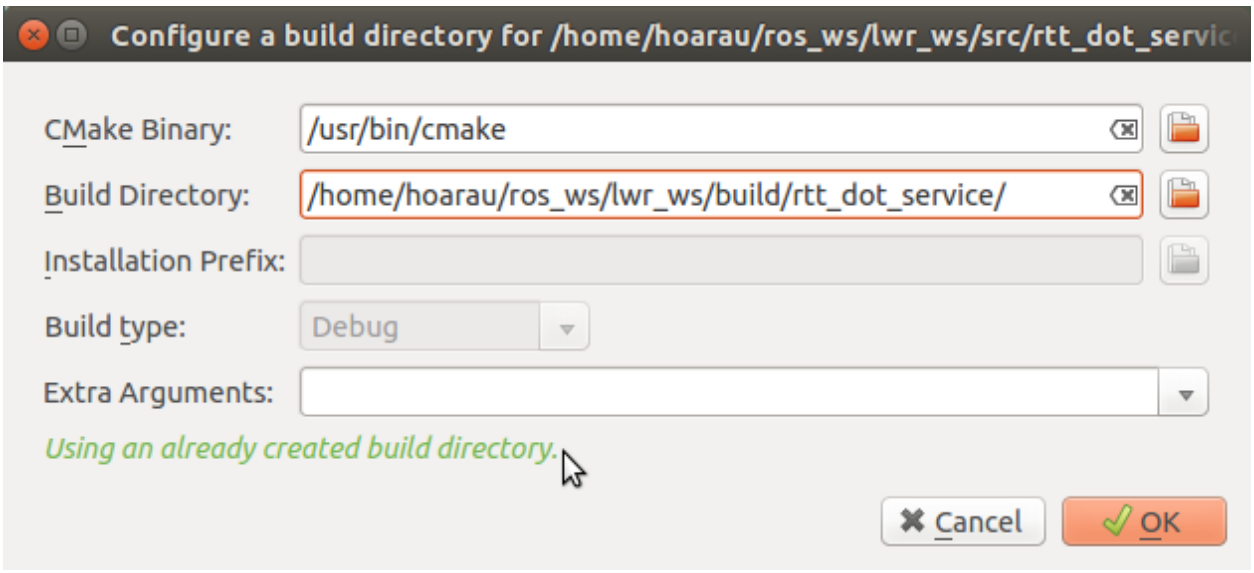
Select the `CMakeLists.txt` inside your project.



Select **you project** as the root directory.

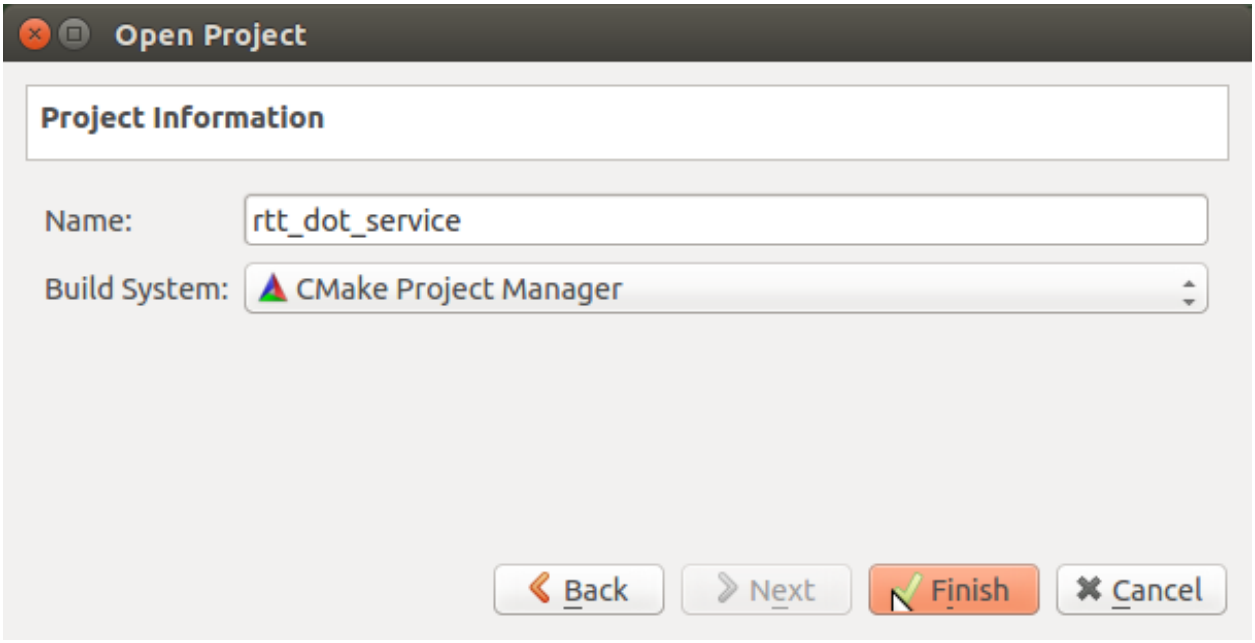


Correct the `Build Directory` if necessary, and if you've already built with `catkin build`, you should see `Using an already created build directory`.



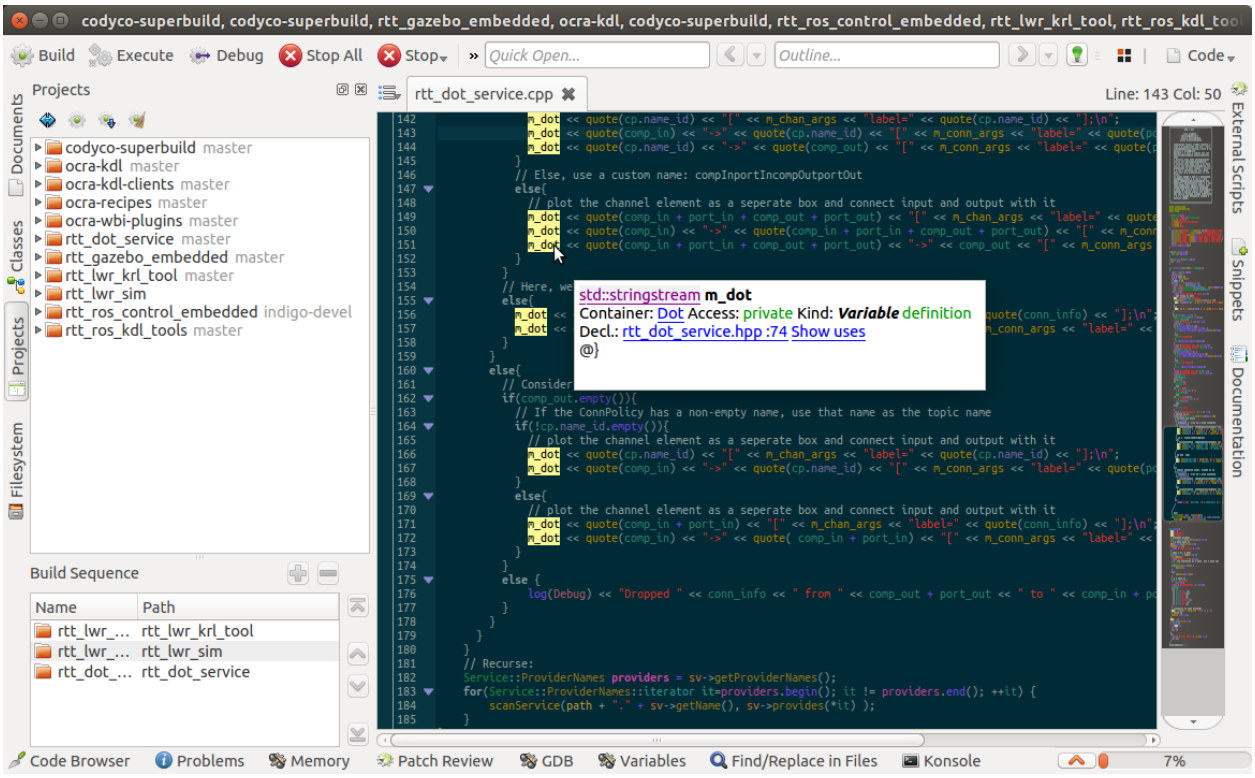
Warning: Make sure the `Build Directory` is set to `/path/to/catkin_ws/build/my_project`.

Click on `finish` and you're done import your project.

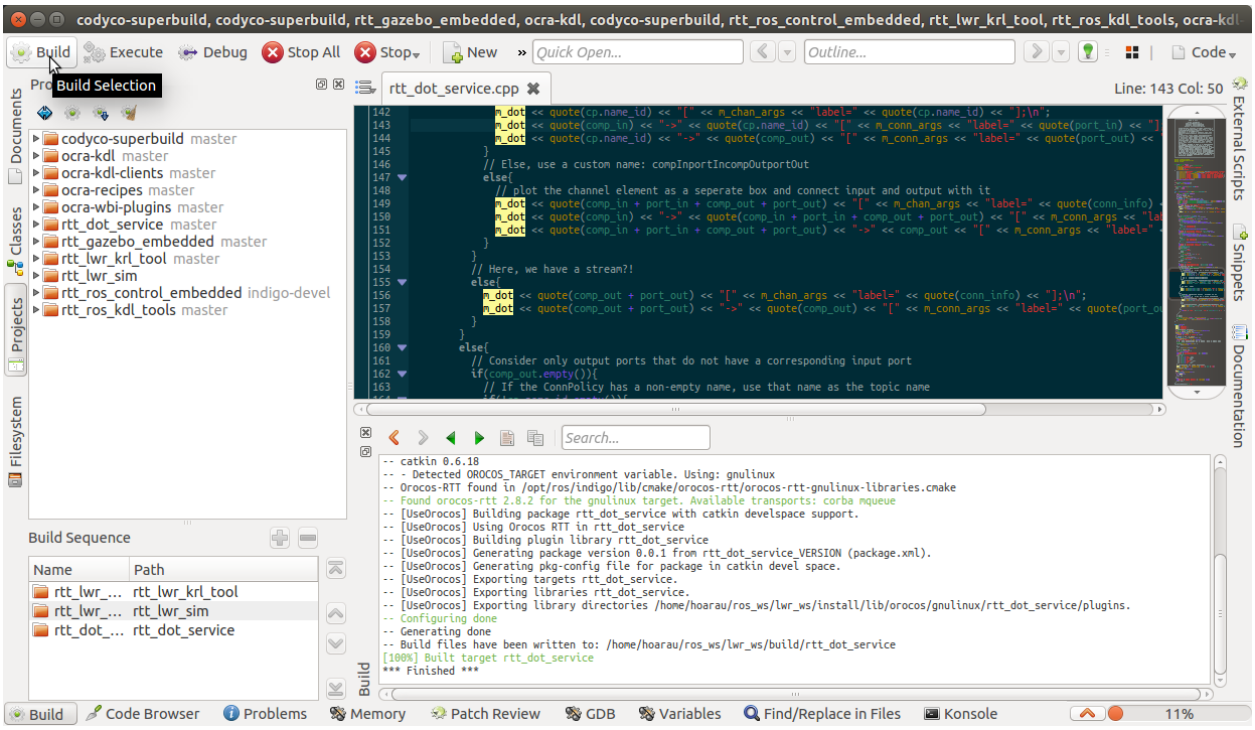


Build your project

On the vertical left panel, click on `Projects` and you'll see the list of your currently opened projects. Yours should appear here afer a few seconds.



You can check also in the `Build Sequence` that your project appears. To build, click on `build` :)



Note: Cliking on `build` is equivalent to calling :

```
cd /path/to/catkin_ws
catkin build my_super_project
```

Update the packages

We are periodically doing updates on the code (new tools, bug fixes etc), so keeping it up-to-date can be very useful.

To update all the packages we're going to use the `vcs-tools` utility (https://github.com/dirk-thomas/vcstool).

It should be already installed during the *installation* procedure, otherwise `sudo apt install python-vcstool`.

Update OROCOS

```
cd ~/isir/orocos-2.9_ws/src
vcs pull
# update submodules for bleeding-edge updates (OPTIONAL)
vcs-git submodule foreach git checkout toolchain-2.9
vcs-git submodule foreach git pull
```

Update RTT ROS Integration

```
cd ~/isir/rtt_ros-2.9/src
vcs pull
```

Update rtt_lwr

```
cd ~/isir/lwr_ws/src
vcs pull
vcs-git submodule update
```

Update the documentation

Locally using sphinx

```
sudo -H pip install sphinx sphinx-autobuild recommonmark sphinx_rtd_theme
```

If you're **not** part of the rtt_lwr developers :

- Create an account on `github`
- Go to rtt_lwr repo and fork it !
- Clone it on your computer : `git clone https://github.com/mysuperaccountname/rtt_lwr`.

Once you have a recent copy of rtt_lwr :

- Go to the docs directory : `roscd rtt_lwr/../docs` and type `make livehtml`.
- Open your favorite webbrowser and go to `127.0.0.1/8000` to see the generated site locally.

Update the doc using your favorite text editor, like atom (https://atom.io).

One updated, `git add -A` and `git commit -m "my super contribution"` and open a pull request, that will be merged once validated.

Directly on github

Simply go to https://github.com/kuka-isir/rtt_lwr and edit files in `docs`. The only drawback is that you can only edit one file at a time.

KRL Tool

RTT/ROS/KDL Tools

Available at https://github.com/kuka-isir/rtt_ros_kdl_tools

This set of tools helps you build and use a robot kinematic model via a provided URDF.

Robot Kinematic Model

The ChainUtils class provides tools to compute forward kinematics, external torques etc. It devrives from ChainUtils-Base and adds **non-realtime** *inverse kinematics* with trac_ik.

Frames of reference / ROS params

To build the kinematic chain, we'll use the folowing ros params :

- `/robot_description` (the URDF uploaded)
- `/root_link` (default/recommended : /link_0)
- `/tip_link` (example : /ati_link)

All those parameters must live in the relative namespace (http://wiki.ros.org/Names) from your node to build the chain with KDL.

Note: If you use the `rtt_lwr` tools, like the generated `run.launch` linked to `lwr_utils`, the params are **automatically** sent when you'll run your controller.

Build your ChainUtils model

In your `package.xml` :

```
<build_depend>rtt_ros_kdl_tools</build_depend>
<run_depend>rtt_ros_kdl_tools</run_depend>
```

In your `CMakeLists.txt` :

```
# Add the rtt_ros dependency
find_package(catkin REQUIRED COMPONENTS rtt_ros)
# It's gonna import all orocos libraries in the package.xml
```

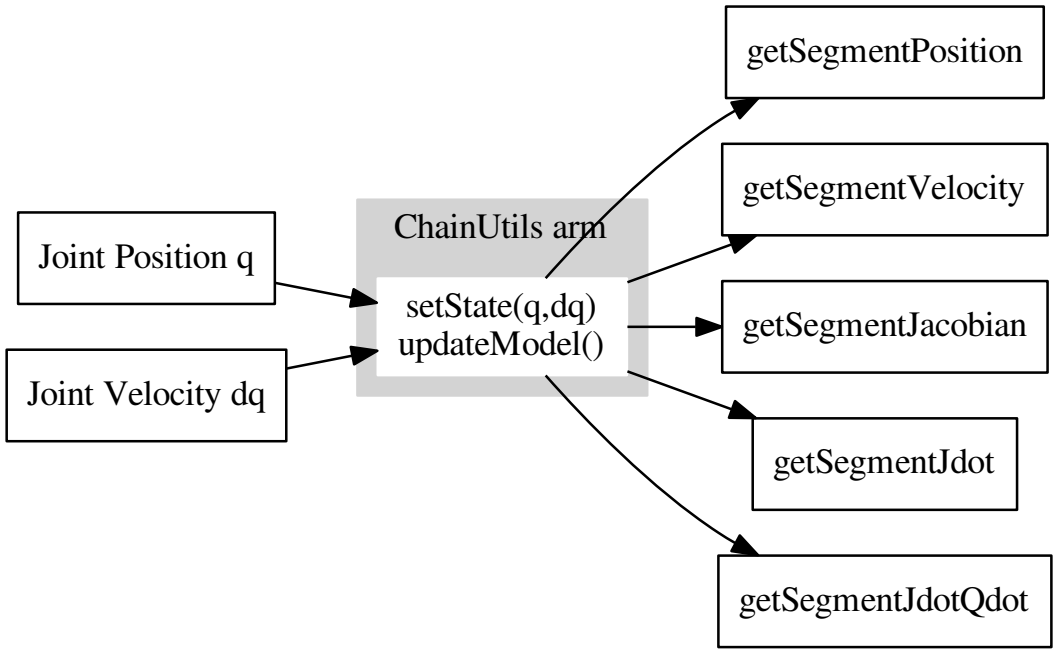
In your `.hpp` :

```
#include <rtt_ros_kdl_tools/chain_utils.hpp>
```

In your `.cpp` :

```
// Construct your model

rtt_ros_kdl_tools::ChainUtils arm;

// Initialise chain from robot_description (via ROS Params)
// It reads /robot_description
//          /tip_link
//          /root_link

arm.init();
```

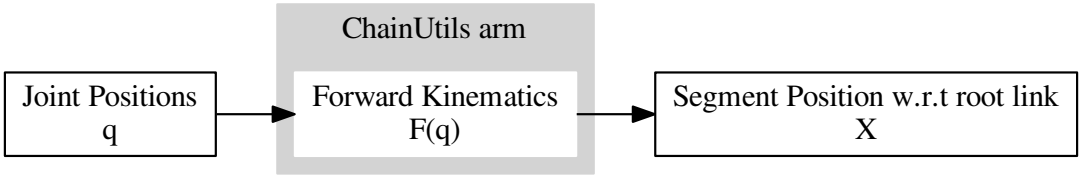
Internal Model



You need to tell `ChainUtils` the state of the robot and compute some internal model variables.

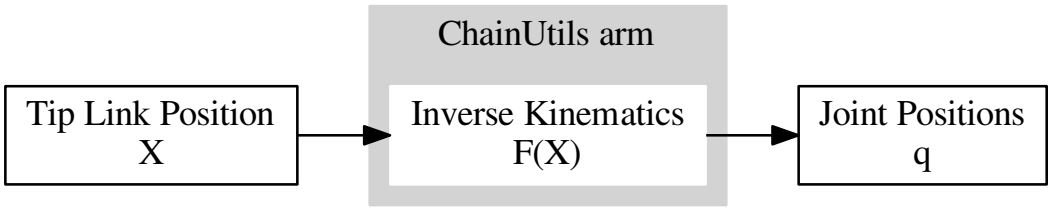
```
// Ex : read from orocos port in an Eigen::VectorXd
port_joint_position_in.read(jnt_pos_in); // Check if RTT::NewData
port_joint_velocity_in.read(jnt_vel_in); // Check if RTT::NewData

// Feed the internal state
arm.setState(jnt_pos_in,jnt_vel_in);
// Update the internal model
arm.updateModel();
```

Forward kinematics




```
// Ex : read from orocos port in an Eigen::VectorXd
port_joint_position_in.read(jnt_pos_in); // Check if RTT::NewData
port_joint_velocity_in.read(jnt_vel_in); // Check if RTT::NewData

// Feed the internal state
arm.setState(jnt_pos_in,jnt_vel_in);
// Update the internal model
arm.updateModel();

// Ex : get a specific segment position
KDL::Frame& X = arm.getSegmentPosition("link_7");

// Ex : get the 5th segment
KDL::Frame& X = arm.getSegmentPosition(5);

// Get Root Link
std::string root_link = arm.getRootSegmentName();
```

Inverse kinematics with trac_ik




```
// Ex : read from orocos port in an Eigen::VectorXd
port_joint_position_in.read(jnt_pos_in); // Check if RTT::NewData
port_joint_velocity_in.read(jnt_vel_in); // Check if RTT::NewData
```

```
// Feed the internal state
arm.setState(jnt_pos_in,jnt_vel_in);
// Update the internal model
arm.updateModel();

// Transform it to a KDL JntArray
KDL::JntArray joint_seed(jnt_pos_in.size());
joint_seed.data = jnt_pos_in;


// Allocate the output of the Inverse Kinematics
KDL::JntArray return_joints(jnt_pos_in.size());

// Create an desired frame
KDL::Frame desired_end_effector_pose(
    KDL::Rotation::RPY(-1.57,0,1.57), // Rotation rad
    KDL::Vector(-0.2,-0.3,0.8));      // Position x,y,z in meters

// Define some tolerances
KDL::Twist tolerances(
    KDL::Vector(0.01,0.01,0.01),   // Tolerance x,y,z in meters
    KDL::Vector(0.01,0.01,0.01));  // Tolerance Rx,Rz,Rz in rad

// Call the inverse function
if(arm.cartesianToJoint(joint_seed,
                        desired_end_effector_pose,
                        return_joints,
                        tolerances))
{
    log(Debug) << "Success ! Result : "
    <<return_joints.data.transpose() << endlog();
}
```

Warning: `trac-ik` is **not realtime-safe** and therefore should not be used in `updateHook()`

Bi-Compilation gnulinux/Xenomai

Tutorial : You are using a gnulinux computer and would like to try to build for xenomai

1. You can install a xenomai kernel and go all xenomai. Please refer to the Xenomai section </>.
2. You can **build** your components to xenomai and test it on another xenomai computer later.

First, get Xenomai libs :

```
wget http://xenomai.org/downloads/xenomai/stable/xenomai-2.6.5.tar.bz2
tar xfvj xenomai-2.6.5.tar.bz2
cd xenomai-2.6-5
mkdir install
./configure --prefix=`pwd`/install
make -j`nproc`
make install
# Now Xenomai is installed in ~/xenomai-2.6-5/install
```

Then clean everything in your orocos workspace :

```
cd orocos-2.9_ws/
catkin clean -y
```

Then add new profiles :

```
catkin profile add xenomai
catkin profile add gnulinux
```

If you run catkin profile list :

```
[profile] Available profiles:
xenomai (active)
default
gnulinux
```

For Xenomai

Use the xenomai profile : `catkin profile set xenomai`.

Let's configure the workspace, the important option is –env-cache as it will save the current environment in a static file (inside orocos-2.9_ws/.catkin_tools). It is only saving when running catkin build !

```
catkin config --extend /opt/ros/indigo \
    --install \
    --env-cache \
    -b build-xenomai   \
    -d devel-xenomai   \
    -i install-xenomai \
    --cmake-args -DCMAKE_BUILD_TYPE=Release \
    -DENABLE_CORBA=ON -DENABLE_MQ=ON -DCORBA_IMPLEMENTATION=OMNIORB
```

Note that we put the build, devel and install space in a different folder so it won't collide with gnulinux builds.

Now you can build !

```
OROCOS_TARGET=xenomai XENOMAI_ROOT_DIR=~/xenomai-2.6.5/install catkin build
```

Note: Now the env var OROCOS_TARGET and XENOMAI_ROOT_DIR are **set/fixed** for all the packages. If you modify them using export, it **won't** affect the ones written for the packages during build.

Once it's done you'll have :

```
hoarau@waro-G55VW:~/ros_ws/orocos-2.9_ws$ ll
total 44
drwxrwxr-x 11 hoarau hoarau 4096 Jul 27 22:48 ./
drwxrwxr-x 15 hoarau hoarau 4096 Jul 27 16:36 ../
drwxrwxr-x 10 hoarau hoarau 4096 Jul 27 22:50 build-xenomai/
drwxrwxr-x  3 hoarau hoarau 4096 May  2 10:13 .catkin_tools/
drwxrwxr-x  5 hoarau hoarau 4096 Jul 27 16:57 devel-xenomai/
drwxrwxr-x  7 hoarau hoarau 4096 Jul 27 22:50 install-xenomai/
drwxrwxr-x 11 hoarau hoarau 4096 Jul 27 22:40 logs/
drwxrwxr-x  4 hoarau hoarau 4096 Jun  7 11:55 src/
```

And inside install-xenomai/lib you'll have -xenomai libraries :

```
lrwxrwxrwx 1 hoarau hoarau 47 Jul 27 16:58 liborocos-ocl-deployment-corba-xenomai.so -
↪> liborocos-ocl-deployment-corba-xenomai.so.2.9.0
```

For gnulinux

Let's use the default profile : `catkin profile set default` Let's configure it the standard way :

```
catkin config --extend /opt/ros/indigo \
    --env-cache \
    -b build \
    -d devel \
    --install \
    -i install \
    --cmake-args -DCMAKE_BUILD_TYPE=Release -DENABLE_CORBA=ON \
    -DENABLE_MQ=ON -DCORBA_IMPLEMENTATION=OMNIORB
```

And build it :

```
OROCOS_TARGET=gnulinux catkin build
```

We now have two version of the same libs (gnulinux/xenomai) :

```
hoarau@waro-G55VW:~/ros_ws/orocos-2.9_ws$ ll
total 44
drwxrwxr-x 11 hoarau hoarau 4096 Jul 27 22:48 ./
drwxrwxr-x 15 hoarau hoarau 4096 Jul 27 16:36 ../
drwxrwxr-x 11 hoarau hoarau 4096 Jul 27 22:40 build/
drwxrwxr-x 10 hoarau hoarau 4096 Jul 27 22:50 build-xenomai/
drwxrwxr-x  3 hoarau hoarau 4096 May  2 10:13 .catkin_tools/
drwxrwxr-x  5 hoarau hoarau 4096 Jul 27 22:40 devel/
drwxrwxr-x  5 hoarau hoarau 4096 Jul 27 16:57 devel-xenomai/
drwxrwxr-x  7 hoarau hoarau 4096 Jul 27 22:41 install/
drwxrwxr-x  7 hoarau hoarau 4096 Jul 27 22:50 install-xenomai/
drwxrwxr-x 11 hoarau hoarau 4096 Jul 27 22:40 logs/
drwxrwxr-x  4 hoarau hoarau 4096 Jun  7 11:55 src/
```

Now let's prove it works :

```
hoarau@waro-G55VW:~/ros_ws/orocos-2.9_ws$ catkin profile list
[profile] Available profiles:
xenomai (active)
default
gnulinux

# Let's check the global linux variable
hoarau@waro-G55VW:~/ros_ws/orocos-2.9_ws$ echo $OROCOS_TARGET
gnulinux

# The next command will show the env variable written on the package rtt cache
# (enabled via catkin config --env-cache)
hoarau@waro-G55VW:~/ros_ws/orocos-2.9_ws$ catkin build --get-env rtt | grep ORO
typeset -x OROCOS_TARGET=xenomai
# We have xenomai written in the cache of the rtt package !
```

We are on xenomai profile, the global linux OROCOS_TARGET is set to gnulinux, but the env written on each package (here rtt) is xenomai !

You can also try to launch to launch the deployer on non-xenomai kernel :

```
hoarau@waro-G55VW:~/ros_ws/orocos-2.9_ws$ source install-xenomai/setup.sh
hoarau@waro-G55VW:~/ros_ws/orocos-2.9_ws$ deployer
Xenomai: /dev/rtheap is missing
(chardev, major=10 minor=254)
# It doest not work, because you don't have a xenomai kernel
```

Final note : on kuka-rt2 (xenomai kernel) it can support both versions !

Compile faster with Ccache and Distcc

- ccache : https://ccache.samba.org/
- distcc : https://github.com/distcc/distcc

Warning: You need to be connected to a high speed network to actually improve your build time

Installation on hosts and clients

```
sudo apt install distcc* ccache distccmon-gnome
```

Build server configuration

On every build computer, you need to install `distcc` and `ccache` and update the configuration :

```
sudo nano /etc/default/distcc
```

Then set he following variables :

```
STARTDISTCC="true"

#
# Which networks/hosts should be allowed to connect to the daemon?
# You can list multiple hosts/networks separated by spaces.
# Networks have to be in CIDR notation, f.e. 192.168.1.0/24
# Hosts are represented by a single IP Adress
#
# ALLOWEDNETS="127.0.0.1"
# This means allow from myself and computers from 192.168.1.0 to 192.168.1.255
ALLOWEDNETS="127.0.0.1 192.168.1.0/24"
```

Restart the distcc deamon and you are all setup ! `sudo service distcc restart`.

Client configuration

```
export CCACHE_PREFIX="distcc"
# Use gcc 4.8 on 14.04
export CC="ccache gcc-4.8" CXX="ccache g++-4.8"
# Use gcc 5 on 16.04
```

```
export CC="ccache gcc-5" CXX="ccache g++-5"
# If you want only distcc use this
#export CC="distcc gcc-4.8" CXX="distcc g++-4.8"
#export CC="distcc gcc-5" CXX="distcc g++-5"

# List here all the known distcc servers/number of threads
export DISTCC_HOSTS='localhost/4 kuka-viz/6 kuka-viz2/6'
```

```
# Build your workspace with
catkin build -p$(distcc -j) -j$(distcc -j) --no-jobserver
```

Tip: Put this alias in your `~/.bashrc`: `alias cdistcc="catkin build -p$(distcc -j) -j$(distcc -j) --no-jobserver"`

Warning: The command in `CC` and `CXX` are the **commands sent** over the network. In order to avoid compiler conflicts, put the compiler version (ex: `gcc-4.8`) !

Building a catkin workspace with Distcc

If you've already built your workspace without distcc, you'll need to **clean** it first *catkin clean -y*. Then, verify you have the variables set correctly (as above) : `echo $CXX && echo $CC`.

Now you can use `catkin build -p$(distcc -j) -j$(distcc -j) --no-jobserver` to build your workspace.

Tip: You can use `distccmon-gnome` to visualize the distribution.

Gazebo Synchronization using Conman

Installation

```
mkdir -p ~/isir/conman_ws/src
cd ~/isir/conman_ws/src
wstool init
wstool merge https://raw.githubusercontent.com/kuka-isir/rtt_lwr/rtt_lwr-2.0/lwr_
↪utils/config/conman.rosinstall
wstool update -j2
cd ~/conman_ws/
# Disable tests on 14.04
catkin config --init --cmake-args -DCATKIN_ENABLE_TESTING=0 -DCMAKE_BUILD_TYPE=Release
# Build
catkin build
```

Gazebo Synchronization using FBSched

As an example you can launch `roslaunch rtt_joint_traj_generator_kdl run.launch sim:=true`. Then in the deployer's console :

```
# Then make sure gazebo follows its executionEngine
gazebo.use_rtt_sync = true
# load the fbs component (default 1Khz)
loadFBSched()

# Set a 1Hz period for the test
fbs.setPeriod(1.0)

# Then for each component
addComponentToFBSched("gazebo")
# This one is not necessary as it is gazebo's slave
addComponentToFBSched("lwr_sim")
# The controller
addComponentToFBSched("lwr_sim_traj_kdl")
# Just for the fun of it
addComponentToFBSched("lwr_sim_state_pub")
addComponentToFBSched("lwr_sim_krl_tool")

# Configure and start FBSched
fbs.configure()
fbs.start()
```

Note: When "fbs" starts, gazebo catches up with all the world's callbacks, so it might jump forward in time. If you put this code in you ops, and pause gazebo, then you won't have any issue.

Xenomai 2.6.5 on Ubuntu 14.04/16.04

Recommended Hardware

- **Intel/AMD Processor i5/i7** (< 2016 is recommended to guaranty full 16.04 support)
- **Dedicated Ethernet controller for RTnet**, with either e1000e/e1000/r8169 driver (Intel PRO/1000 GT recommended)

Warning: Nvidia Drivers are NOT supported (creates a lot of interruptions that breaks the real-time). Please consider removing the dedicated graphic card and use the integrated graphics (Intel HD graphics).

Download Xenomai 2.6.5

```
wget http://xenomai.org/downloads/xenomai/stable/xenomai-2.6.5.tar.bz2
tar xfvj xenomai-2.6.5.tar.bz2
```

Download Linux kernel 3.18.20

```
wget https://www.kernel.org/pub/linux/kernel/v3.x/linux-3.18.20.tar.gz
tar xfv linux-3.18.20.tar.gz
```

Note: We chose 3.18.20 because it is the latest kernel compatible with xenomai 2.

Configuration

Prevent a bug in make-kpkg in 14.04

From https://bugs.launchpad.net/ubuntu/+source/kernel-package/+bug/1308183 :

```
cd linux-3.18.20
# Paste that in the terminal
cat <<EOF > arch/x86/boot/install.sh
#!/bin/sh
cp -a -- "\$2" "\$4/vmlinuz-\$1"
EOF
```

Prepare the kernel

```
sudo apt install kernel-package
```

Patch the Linux kernel with Xenomai ipipe patch

```
cd linux-3.18.20
../xenomai-2.6.5/scripts/prepare-kernel.sh
```

Press Enter to use the default options.

Configure the kernel

Now it's time to configure :

Gui version :

```
make xconfig
```

Or without gui :

```
sudo apt install libncurses5-dev
make menuconfig
```

Some guidelines to configure the linux kernel:

```
Recommended options:

* General setup
  --> Local version - append to kernel release: -xenomai-2.6.5
  --> Timers subsystem
      --> High Resolution Timer Support (Enable)
* Real-time sub-system
  --> Xenomai (Enable)
  --> Nucleus (Enable)
```

```
* Power management and ACPI options
  --> Run-time PM core functionality (Disable)
  --> ACPI (Advanced Configuration and Power Interface) Support
      --> Processor (Disable)
  --> CPU Frequency scaling
      --> CPU Frequency scaling (Disable)
  --> CPU idle
      --> CPU idle PM support (Disable)
* Processor type and features
  --> Processor family
      --> Core 2/newer Xeon (if \"cat /proc/cpuinfo | grep family\" returns 6, set as␣
↪Generic otherwise)
* Power management and ACPI options
  --> Memory power savings
      --> Intel chipset idle memory power saving driver
```

Warning: For OROCOS, we need to increase the amount of ressources available for Xenomai tasks, otherwise we might hit the limits quickly as we add multiples components/ports etc. http://www.orocos.org/forum/orocos/orocos-users/orocos-limits-under-xenomai

```
* Real-time sub-system
  --> Number of registry slots
      --> 4096
  --> Size of the system heap
      --> 2048 Kb
  --> Size of the private stack pool
      --> 1024 Kb
  --> Size of private semaphores heap
      --> 48 Kb
  --> Size of global semaphores heap
      --> 48 Kb
```

Save the config and close the gui.

Compile the kernel (make debians)

Now it's time to compile.

```
CONCURRENCY_LEVEL=$(nproc) make-kpkg --rootcmd fakeroot --initrd kernel_image kernel_
↪headers
```

Take a coffee and come back in 20min.

Compile faster with distcc

```
MAKEFLAGS="CC=distcc" BUILD_TIME="/usr/bin/time" CONCURRENCY_LEVEL=$(distcc -j) make-
↪kpkg --rootcmd fakeroot --initrd kernel_image kernel_headers
```

Install the kernel

```
cd ..
sudo dpkg -i linux-headers-3.18.20-xenomai-2.6.5_3.18.20-xenomai-2.6.5-10.00.Custom_
↪amd64.deb linux-image-3.18.20-xenomai-2.6.5_3.18.20-xenomai-2.6.5-10.00.Custom_
↪amd64.deb
```

Allow non-root users

```
sudo addgroup xenomai --gid 1234
sudo addgroup root xenomai
sudo usermod -a -G xenomai $USER
```

Tip: If the addgroup command fails (ex: GID `xenomai` is already in use), change it to a different random value, and report it in the next section.

Configure GRUB

Edit the grub config :

```
sudo nano /etc/default/grub
```

```
GRUB_DEFAULT=saved
GRUB_SAVEDEFAULT=true
#GRUB_HIDDEN_TIMEOUT=0
#GRUB_HIDDEN_TIMEOUT_QUIET=true
GRUB_TIMEOUT=5
GRUB_CMDLINE_LINUX_DEFAULT="quiet splash xeno_nucleus.xenomai_gid=1234 xenomai.
↪allowed_group=1234"
GRUB_CMDLINE_LINUX=""
```

Note: Please note the xenomai group (here 1234) should match what you set above (allow non-root users).

Tip: `noapic` option might be added if the screen goes black at startup and you can't boot.

If you have an Intel HD Graphics integrated GPU (any type) :

```
GRUB_CMDLINE_LINUX_DEFAULT="quiet splash i915.enable_rc6=0 i915.powersave=0 noapic␣
↪xeno_nucleus.xenomai_gid=1234 xenomai.allowed_group=1234"
# This removes powersavings from the graphics, that creates disturbing interruptions.
```

If you have an Intel **Skylake** (2015 processors), you `need` to add nosmap to fix the latency hang (https://xenomai.org/pipermail/xenomai/2016-October/036787.html) :

```
GRUB_CMDLINE_LINUX_DEFAULT="quiet splash i915.enable_rc6=0 i915.powersave=0 xeno_
↪nucleus.xenomai_gid=1234 nosmap"
```

Update GRUB and reboot

```
sudo update-grub
sudo reboot
```

Install Xenomai libraries

```
cd xenomai-2.6.5/
./configure
make -j$(nproc)
sudo make install
```

Update your bashrc

```
echo '
#### Xenomai
export XENOMAI_ROOT_DIR=/usr/xenomai
export XENOMAI_PATH=/usr/xenomai
export PATH=$PATH:$XENOMAI_PATH/bin
export PKG_CONFIG_PATH=$PKG_CONFIG_PATH:$XENOMAI_PATH/lib/pkgconfig
export LD_LIBRARY_PATH=$LD_LIBRARY_PATH:$XENOMAI_PATH/lib
export OROCOS_TARGET=xenomai
' >> ~/.bashrc
```

Test your installation

```
xeno latency
```

This loop will allow you to monitor a xenomai latency. Here's the output for a i7 4Ghz :

```
== Sampling period: 100 us
== Test mode: periodic user-mode task
== All results in microseconds
warming up...
RTT|  00:00:01  (periodic user-mode task, 100 us period, priority 99)
RTH|----lat min|----lat avg|----lat max|-overrun|---msw|---lat best|--lat worst
RTD|      0.174|      0.464|      1.780|       0|     0|      0.174|      1.780
RTD|      0.088|      0.464|      1.357|       0|     0|      0.088|      1.780
RTD|      0.336|      0.464|      1.822|       0|     0|      0.088|      1.822
RTD|      0.342|      0.464|      1.360|       0|     0|      0.088|      1.822
RTD|      0.327|      0.462|      2.297|       0|     0|      0.088|      2.297
RTD|      0.347|      0.463|      1.313|       0|     0|      0.088|      2.297
RTD|      0.314|      0.464|      1.465|       0|     0|      0.088|      2.297
RTD|      0.190|      0.464|      1.311|       0|     0|      0.088|      2.297
```

Tip: To get pertinent results, you need to **stress** your system. to do so, you can use `stress` or `dohell` from the `apt`.

```
# Using stress
stress -v -c 8 -i 10 -d 8
```

Negative latency issues

You need to be in root `sudo -s`, then you can set values to the latency calibration variable in **nanoseconds**:

```
$ echo 0 > /proc/xenomai/latency
# Now run the latency test

# If the minimum latency value is positive,
# then get the lowest value from the latency test (ex: 0.088 us)
# and write it to the calibration file ( here you have to write 88 ns) :
$ echo my_super_value_in_ns > /proc/xenomai/latency
```

Source : https://xenomai.org/pipermail/xenomai/2007-May/009063.html

RTnet setup on Xenomai

Official website : http://www.rtnet.org/index.html

RTnet allows you to send and receive data with very strict constraints, in a real-time environment (RTAI, Xenomai). It only works with a very limited set of ethernet cards (RTnet includes "real-time" re-written drivers) : Intel PRO/1000, 82574L, any card with r8169 (xenomai < 2.6.4 only) and others.

First make sure your followed the Xenomai installation instructions and you are running the Xenomai kernel (uname -a).

Recommended hardware

- Intel Pro/1000 GT : e1000e driver <– *Recommended*
- D-Link DGE-528T : r8169s driver

Check which kernel driver you use

```
lspci -vvv -nn | grep -C 10 Ethernet
```

And check if the **rt**_ version exists in RTnet's drivers.

Note: We're using a custom website that fixes compilation problems for kernel > 3.10 source.

Download

```
sudo apt install git
```

```
git clone https://github.com/kuka-isir/RTnet.git
```

Installation

We'll need the following options:

```
* Variant
  --> Xenomai 2.1
* Protocol Stack
  --> TCP Support (for ATI Force Sensor)
* Drivers
  --> The driver you use (New Intel PRO/1000 in our case)
  --> Loopback (optional)
* Add-Ons
  --> Real-Time Capturing Support (optional, for Wireshark debugging)
* Examples
  --> RTnet Application Examples
      --> Enable (optional)
```

```
sudo apt install libncurses5-dev
```

```
cd RTnet
make menuconfig
# Configure the options below
# Then hit ESC 2 times, save the config, and build
make
# Install in /usr/local/rtnet/ (default location)
sudo make install
```

Configuration

The configuration file is located by default at `/usr/local/rtnet/etc/rtnet.conf` Take a look at this configuration file.

- **RT_DRIVER="rt_e1000e"** The driver we use (we have the Intel PRO/1000 GT)
- **REBIND_RT_NICS="0000:05:00.0 0000:06:00.0"** NIC addresses of the 2 cards we use for RTnet (you can check the NIC address typing 'lshw -C network' and looking at "bus info: pci@...". It is useful to have a fix master/slave config order (card1->robot, card2->Sensor for example).
- **IPADDR="192.168.100.101"** IP of the master (your computer). ALl the slaves will send/receive to/from master IP.
- **NETMASK="255.255.255.0"** The other slave will have IPs 192.168.100.XXX.
- **RT_LOOPBACK="no"** Not used now. Might be useful to use it somehow.
- **RT_PROTOCOLS="udp packet tcp"** Robot sends via UDP, ATI Sensor via TCP for config, UDP otherwise.
- **RTCAP="yes"** To debug with Wireshark
- **TDMA_CYCLE="450"** and **TDMA_OFFSET="50"** Data from robot/ sensor takes about 350us to receive (using Wireshark).

Allow non-root users

To allow commands like `rtnet start` etc to be used without `sudo`, we will use `visudo`. We remove password in certain commands *only for people in the xenomai group*.

```
sudo visudo
# then add the following at the end
%xenomai ALL=(root) NOPASSWD:/sbin/insmod
%xenomai ALL=(root) NOPASSWD:/sbin/rmmod
%xenomai ALL=(root) NOPASSWD:/sbin/modprobe
%xenomai ALL=(root) NOPASSWD:/bin/echo
%xenomai ALL=(root) NOPASSWD:/bin/mknod
%xenomai ALL=(root) NOPASSWD:/usr/bin/service
%xenomai ALL=(root) NOPASSWD:/usr/sbin/service
%xenomai ALL=(root) NOPASSWD:/usr/local/rtnet/sbin/rtcfg
%xenomai ALL=(root) NOPASSWD:/usr/local/rtnet/sbin/rtifconfig
%xenomai ALL=(root) NOPASSWD:/usr/local/rtnet/sbin/rtiwconfig
%xenomai ALL=(root) NOPASSWD:/usr/local/rtnet/sbin/rtnet
%xenomai ALL=(root) NOPASSWD:/usr/local/rtnet/sbin/rtping
%xenomai ALL=(root) NOPASSWD:/usr/local/rtnet/sbin/rtroute
%xenomai ALL=(root) NOPASSWD:/usr/local/rtnet/sbin/tdmacfg
```

Test your installation

Using the test script

A launch script can be found here. Adjust the following settings to your needs :

- SLAVES="192.168.100.102 192.168.100.103"
- SLAVES_NAMES="Kuka ATISensor"

Then to use it :

```
./path/to/script/rtnet start
```

Manually

```
cd /usr/local/rtnet/sbin
# Start the rt kernel drivers
sudo ./rtnet start
# Bringup connection
sudo ./rtifconfig rteth0 up 192.168.100.101 netmask 255.255.255.0
# Bringup slaves
sudo ./rtroute solicit 192.168.100.102 dev rteth0
# Ping Slave
sudo ./rtping 192.168.100.102
# Stop everything
sudo ./rtnet stop
```

Note: You might have to remove the non-rt kernel driver before rtnet start :

```
sudo rmmod e1000e
sudo ./rtnet start
```

Note: You should see rt_e1000e as the kernel driver currently used

```
lspci -vvv -nn | grep -C 10 Ethernet
lsmod | grep rt_
```

Use RTnet in C++

The API is the same as regular socket in C, except that the functions start with `rt_*`. To make sure it compiles on every platform, add the following to your headers :

```
#ifndef HAVE_RTNET

// Rename the standard functions
// And use theses ones to be RTnet-compatible when available

#define rt_dev_socket     socket
#define rt_dev_setsockopt setsockopt
#define rt_dev_bind       bind
#define rt_dev_recvfrom   recvfrom
#define rt_dev_sendto     sendto
#define rt_dev_close      close
#define rt_dev_connect    connect

#else
// Use RTnet in Xenomai
#include <rtdm/rtdm.h>
#endif
```

And in your CMakeLists.txt (example) :

```
# Add the path to the FindRTnet.cmake folder
# Let's assume you put it in /path/to/project/cmake
list(APPEND CMAKE_MODULE_PATH ${PROJECT_SOURCE_DIR}/cmake)

if($ENV{OROCOS_TARGET} STREQUAL "xenomai")
  find_package(RTnet)
  if(NOT ${RTnet_FOUND})
    message(ERROR "RTnet cannot be used without Xenomai")
  else()
    message(STATUS "RTnet support enabled")
    set_property(TARGET ${TARGET_NAME} APPEND PROPERTY COMPILE_DEFINITIONS HAVE_RTNET␣
↪XENOMAI)
  endif()
endif()
```

Note: FindRTnet.cmake can be found here.

OROCOS RTT on Xenomai

Orocos RTT is fully compatible with Xenomai, but it needs to be built *from source*.

Please follow the installation instructions to build OROCOS.

The only difference is the need to set `export OROCOS_TARGET=xenomai` before compiling.

```
echo 'export OROCOS_TARGET=xenomai' >> ~/.bashrc
source ~/.bashrc
# Now you can build orocos with the standard instructions
# Make sure you cleaned the workspace first !
```

Note: Xenomai has to be setup correctly prior to building OROCOS.

Note: Remember to `clean` your workspace prior to compiling (`catkin clean -y`)