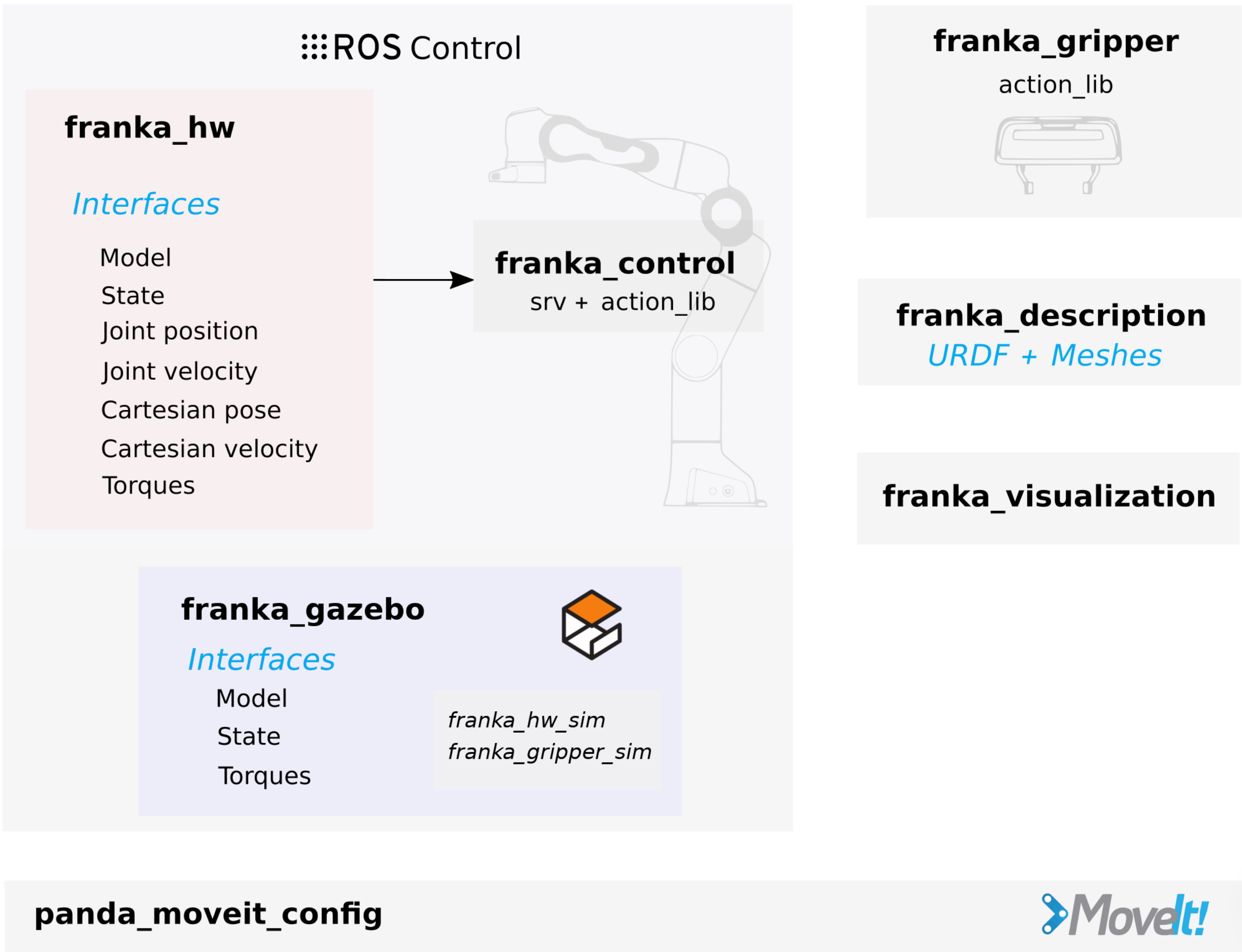
franka_ros

Note

`franka_ros` is not supported on Windows.

Before continuing with this chapter, please install or compile franka_ros.

You can access the changelog of franka_ros at this link



Schematic overview of the `franka_ros` *packages.*

The `franka_ros` metapackage integrates `libfranka` into ROS and ROS control. Here, we introduce its packages and we also give a short how-to for writing controllers.

All parameters passed to launch files in this section come with default values, so they can be omitted if using the default network addresses and ROS namespaces. Make sure the `source` command was called with the setup script from your workspace:

```
source /path/to/catkin_ws/devel/setup.sh
```

franka_description

This package contains the description of our robots and end effectors in terms of kinematics, joint limits, visual surfaces and collision space. The collision space is a simplified version of the visual description used to improve performance of collision checks. The descriptions are based on the URDF format according to the URDF XML documentation .

If you want to simulate the FR3 robots, you can pass a `gazebo` argument to the XACRO file. franka_description contains the files for all the Franka Robotics robot models.

```
xacro $(rospack find franka_description)/robots/fr3/fr3.urdf.xacro gazebo:=true
```

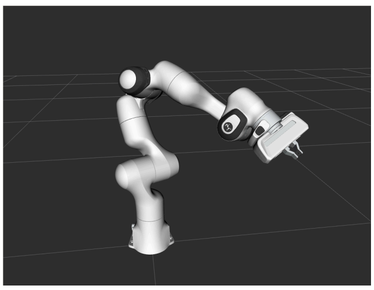
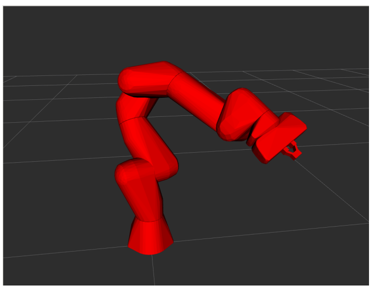
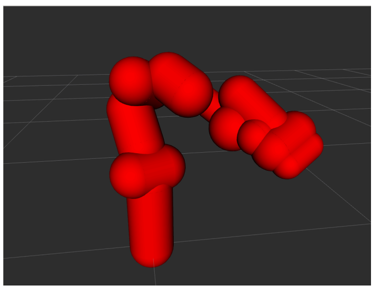
The same works for FER(Panda):

```
xacro $(rospack find franka_description)/robots/panda/panda.urdf.xacro gazebo:=true
```

Collisions Volumes

The URDF defines two types of collision types:

- **Fine**: These collision volumes are made from convex meshes which are approximated and drastically simplified versions of the visual meshes (.dae) of each link. The fine volumes should be used for simulating robot collisions in Gazebo
- **Coarse**: These collision volumes are simply capsules (a cylinder with two semispherical end caps) attached to each link and inflated by a certain safety distance. These volumes are more efficient to compute and are used internally in the robot for self-collision avoidance. Use these geometries when you are planning motions e.g. with MoveIt.

Visual	Collision (Fine)	Collision (Coarse)
		

To distinguish between the two types of collision models artificial links are inserted in the URDF with an `*_sc` suffix (for self-collision):

```
panda_link0
├─ panda_link0_sc
└─ panda_link1
   ├─ panda_link1_sc
   └─ panda_link2
      ├─ panda_link2_sc
      └─ panda_link3
         ├─ panda_link3_sc
         └─ panda_link4
            ├─ panda_link4_sc
            └─ panda_link5
               ├─ panda_link5_sc
               └─ panda_link6
                  ├─ panda_link6_sc
                  └─ panda_link7
                     ├─ panda_link7_sc
                     └─ panda_link8
                        ├─ panda_link8_sc
                        └─ panda_hand
                           ├─ panda_leftfinger
                           ├─ panda_rightfinger
                           ├─ panda_hand_sc
                           └─ panda_hand_tcp
```

You can control which collision model is loaded into your URDF via the `gazebo` XACRO argument:

- `xacro ... panda.urdf.xacro gazebo:=false`: This will use *both* the fine and coarse collision model. This is also the default if you omit the arg entirely. Use this when you want to use MoveIt
- `xacro ... panda.urdf.xacro gazebo:=true`: This will use *only* the fine collision model. Use this when you want a simulatable URDF i.e. for Gazebo. When using the coarse collision model the robot will of course be in constant collision with the capsules of the next link.

franka_gripper

This package implements the `franka_gripper_node` for interfacing a gripper from ROS. The node publishes the state of the gripper and offers the following *actions servers*:

- `franka_gripper::MoveAction(width, speed)`: moves to a target `width` with the defined `speed`.
- `franka_gripper::GraspAction(width, epsilon_inner, epsilon_outer, speed, force)`: tries to grasp at the desired `width` with a desired `force` while closing with the given `speed`. The operation is successful if the distance d between the gripper fingers is: $\text{width} - \epsilon_\text{inner} < d < \text{width} + \epsilon_\text{outer}$.
- `franka_gripper::HomingAction()`: homes the gripper and updates the maximum width given the mounted fingers.
- `franka_gripper::StopAction()`: aborts a running action. This can be used to stop applying forces after grasping.
- `control_msgs::GripperCommandAction(width, max_effort)`: A standard gripper action recognized by MoveIt!. If the argument `max_effort` is greater than zero, the gripper will try to grasp an object of the desired `width`. On the other hand, if `max_effort` is zero ($\text{max\_effort} < 1^{-4}$), the gripper will move to the desired `width`.

> **Note**
>
> Use the argument `max_effort` only when grasping an object, otherwise, the gripper will close ignoring the `width` argument.

You can launch the `franka_gripper_node` with:

```
roslaunch franka_gripper franka_gripper.launch robot_ip:=<fci-ip>
```

> **Hint**
>
> Starting with `franka_ros` 0.6.0, specifying `load_gripper:=true` for `roslaunch franka_control franka_control.launch` will start a `franka_gripper_node` as well.

franka_hw

This package contains the hardware abstraction of the robot for the ROS control framework based on the `libfranka` API. The hardware class `franka_hw::FrankaHW` is implemented in this package offering the following interfaces to controllers:

Interface	Function
`hardware_interface::JointStateInterface`	Reads joint states.
`hardware_interface::VelocityJointInterface`	Commands joint velocities and reads joint states.
`hardware_interface::PositionJointInterface`	Commands joint positions and reads joint states.

Interface	Function
`hardware_interface::EffortJointInterface`	Commands joint-level torques and reads joint states.
`franka_hw::FrankaStateInterface`	Reads the full robot state.
`franka_hw::FrankaPoseCartesianInterface`	Commands Cartesian poses and reads the full robot state.
`franka_hw::FrankaVelocityCartesianInterface`	Commands Cartesian velocities and reads the full robot state.
`franka_hw::FrankaModelInterface`	Reads the dynamic and kinematic model of the robot.

To use ROS control interfaces, you have to retrieve resource handles by name:

Interface	Resource handle name
`hardware_interface::JointStateInterface`	“<arm_id>_joint1” to “<arm_id>_joint7”
`hardware_interface::VelocityJointInterface`	“<arm_id>_joint1” to “<arm_id>_joint7”
`hardware_interface::PositionJointInterface`	“<arm_id>_joint1” to “<arm_id>_joint7”
`hardware_interface::EffortJointInterface`	“<arm_id>_joint1” to “<arm_id>_joint7”
`franka_hw::FrankaStateInterface`	“<arm_id>_robot”
`franka_hw::FrankaPoseCartesianInterface`	“<arm_id>_robot”
`franka_hw::FrankaVelocityCartesianInterface`	“<arm_id>_robot”
`franka_hw::FrankaModelInterface`	“<arm_id>_robot”

Hint

By default, <arm_id> is set to “panda”.

The `franka_hw::FrankaHW` class also implements the starting, stopping and switching of controllers.

The `FrankaHW` class also serves as base class for `FrankaCombinableHW`, a hardware class that can be combined with others to control multiple robots from a single controller. The combination of an arbitrary number of Panda robots (number configured by parameters) based on `FrankaCombinableHW` for the ROS control framework https://github.com/ros-controls/ros_control is implemented in `FrankaCombinedHW`. The key-difference between `FrankaHW` and `FrankaCombinedHW` is that the latter supports torque control only.

Important

The `FrankaCombinableHW` class is available from version 0.7.0 and allows torque/effort control only.

The ROS parameter server is used to determine at runtime which robots are loaded in the combined class. For an example on how to configure the `FrankaCombinedHW` in the according hardware node, see franka_control.

Note

The approach of `FrankaHW` is optimal for controlling single robots. Thus we recommend using the `FrankaCombinableHW` / `FrankaCombinedHW` classes only for controlling multiple robots.

The interfaces offered by the `FrankaCombinableHW` / `FrankaCombinedHW` classes are the following:

Interface	Function
`hardware_interface::EffortJointInterface`	Commands joint-level torques and reads joint states.
`hardware_interface::JointStateInterface`	Reads joint states.
`franka_hw::FrankaStateInterface`	Reads the full robot state.
`franka_hw::FrankaModelInterface`	Reads the dynamic and kinematic model of the robot.

The only admissible command interface claim is the `EffortJointInterface` which can be combined with any set of read-only-interfaces (`FrankaModelInterface` , `JointStateInterface` , `FrankaStateInterface`). The resource handles offered by all interfaces are claimed by name and follow the same naming conventions as described for *FrankaHW*. Every instance of `FrankaCombinableHW` offers the complete set of service and action interfaces (see franka_control).

Note

The `FrankaCombinedHW` class offers an additional action server in the control node namespace to recover all robots. If a reflex or error occurs on any of the robots, the control loop of all robots stops until they are recovered.

Important

`FrankaHW` makes use of the ROS joint_limits_interface to enforce position, velocity and effort safety limits. The utilized interfaces are listed below:

- joint_limits_interface::PositionJointSoftLimitsInterface
- joint_limits_interface::VelocityJointSoftLimitsInterface
- joint_limits_interface::EffortJointSoftLimitsInterface

Approaching the limits will result in the (unannounced) modification of the commands.

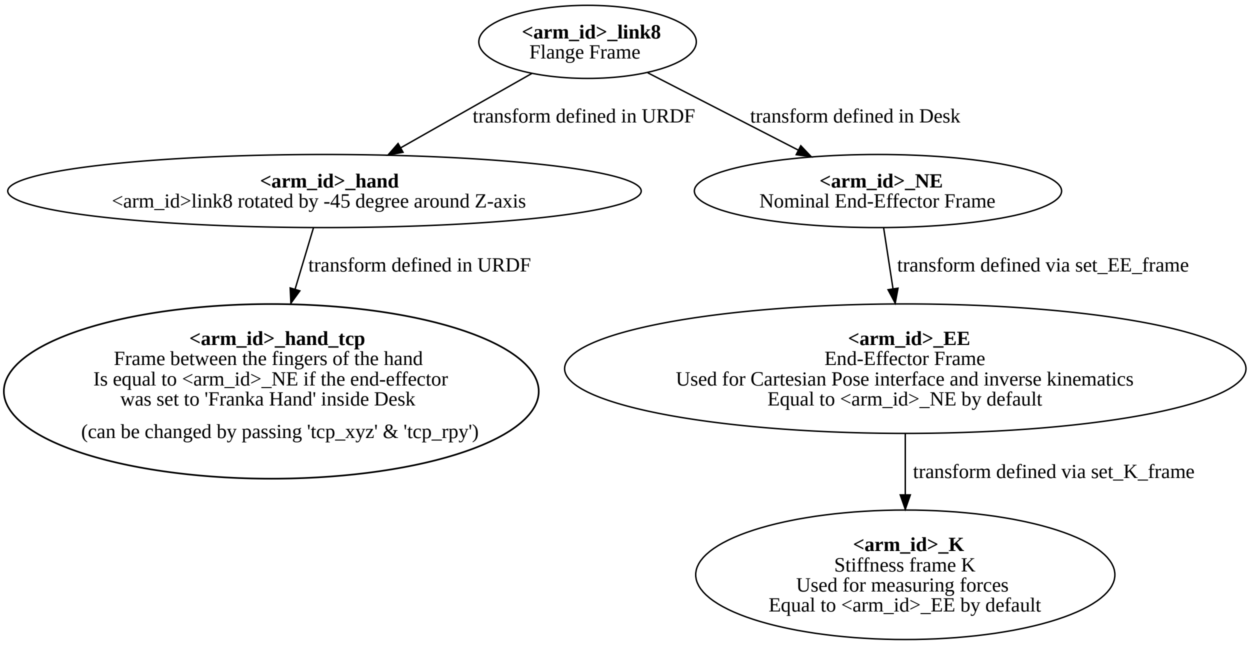
franka_control

The ROS nodes `franka_control_node` and `franka_combined_control_node` are hardware nodes for ROS control that use according hardware classes from `franka_hw`. They provide a variety of ROS services to expose the full `libfranka` API in the ROS ecosystem. The following services are provided:

- `franka_msgs::SetJointImpedance` specifies joint stiffness for the internal controller (damping is automatically derived from the stiffness).
- `franka_msgs::SetCartesianImpedance` specifies Cartesian stiffness for the internal controller (damping is automatically derived from the stiffness).
- `franka_msgs::SetEEFrame` specifies the transformation from <arm_id>_EE (end effector) to <arm_id>_NE (nominal end effector) frame. The transformation from flange to end effector frame is split into two transformations: <arm_id>_EE to <arm_id>_NE frame and <arm_id>_NE to <arm_id>_link8 frame. The transformation from <arm_id>_NE to <arm_id>_link8 frame can only be set through the administrator's interface.
- `franka_msgs::SetKFrame` specifies the transformation from <arm_id>_K to <arm_id>_EE frame.
- `franka_msgs::SetForceTorqueCollisionBehavior` sets thresholds for external Cartesian wrenches to configure the collision reflex.
- `franka_msgs::SetFullCollisionBehavior` sets thresholds for external forces on Cartesian and joint level to configure the collision reflex.
- `franka_msgs::SetLoad` sets an external load to compensate (e.g. of a grasped object).
- `std_srvs::Trigger` services allow to connect and disconnect your hardware node (available from 0.8.0). When no active (commanding) controller is running, you can disconnect the hardware node, freeing the respective robots for non-fci applications like e.g. Desk-based operations. Once you want to resume fci operations you can call connect and start your ros_control based controllers again.

Important

The <arm_id>_EE frame denotes the part of the configurable end effector frame which can be adjusted during run time through *franka_ros*. The <arm_id>_K frame marks the center of the internal Cartesian impedance. It also serves as a reference frame for external wrenches. *Neither the <arm_id>_EE nor the <arm_id>_K are contained in the URDF as they can be changed at run time*. By default, <arm_id> is set to "panda".



Overview of the end-effector frames.

To recover from errors and reflexes when the robot is in reflex mode, you can utilize the `franka_msgs::ErrorRecoveryAction`. This can be achieved through either an action client or by publishing on the action goal topic.

```
rostopic pub -1 /franka_control/error_recovery/goal
franka_msgs/ErrorRecoveryActionGoal "{}"
```

After recovery, the `franka_control_node` restarts the controllers that were running. That is possible as the node does not die when robot reflexes are triggered or when errors have occurred. All of these functionalities are provided by the `franka_control_node` which can be launched with the following command:

```
roslaunch franka_control franka_control.launch \
robot_ip:=<fci-ip> # mandatory \
load_gripper:=<true|false> # default: true \
robot:=<panda|fr3> # default: panda
```

Besides loading the `franka_control_node`, the launch file also starts a `franka_control::FrankaStateController` for reading and publishing the robot states, including external wrenches, configurable transforms and the joint states required for visualization with rviz. For visualization purposes, a `robot_state_publisher` is started.

This package also implements the `franka_combined_control_node`, a hardware node for `ros_control` based on the `franka_hw::FrankaCombinedHW` class. The set of robots loaded are configured via the ROS parameter server. These parameters have to be in the hardware node's namespace (see franka_combined_control_node.yaml as a reference) and look like this:

```yaml
robot_hardware:
  - panda_1
  - panda_2
  # (...)

panda_1:
  type: franka_hw/FrankaCombinableHW
  arm_id: panda_1
  joint_names:
    - panda_1_joint1
    - panda_1_joint2
    - panda_1_joint3
    - panda_1_joint4
    - panda_1_joint5
    - panda_1_joint6
    - panda_1_joint7
  # Configure the threshold angle for printing joint limit warnings.
  joint_limit_warning_threshold: 0.1 # [rad]
  # Activate rate limiter? [true|false]
  rate_limiting: true
  # Cutoff frequency of the low-pass filter. Set to >= 1000 to deactivate.
  cutoff_frequency: 1000
  # Internal controller for motion generators [joint_impedance|cartesian_impedance]
  internal_controller: joint_impedance
  # Configure the initial defaults for the collision behavior reflexes.
  collision_config:
    lower_torque_thresholds_acceleration: [20.0, 20.0, 18.0, 18.0, 16.0, 14.0, 12.0] # [Nm]
    upper_torque_thresholds_acceleration: [20.0, 20.0, 18.0, 18.0, 16.0, 14.0, 12.0] # [Nm]
    lower_torque_thresholds_nominal: [20.0, 20.0, 18.0, 18.0, 16.0, 14.0, 12.0]  # [Nm]
    upper_torque_thresholds_nominal: [20.0, 20.0, 18.0, 18.0, 16.0, 14.0, 12.0]  # [Nm]
    lower_force_thresholds_acceleration: [20.0, 20.0, 20.0, 25.0, 25.0, 25.0]  # [N, N, N, Nm, Nm, Nm]
    upper_force_thresholds_acceleration: [20.0, 20.0, 20.0, 25.0, 25.0, 25.0]  # [N, N, N, Nm, Nm, Nm]
    lower_force_thresholds_nominal: [20.0, 20.0, 20.0, 25.0, 25.0, 25.0]  # [N, N, N, Nm, Nm, Nm]
    upper_force_thresholds_nominal: [20.0, 20.0, 20.0, 25.0, 25.0, 25.0]  # [N, N, N, Nm, Nm, Nm]

panda_2:
  type: franka_hw/FrankaCombinableHW
  arm_id: panda_2
  joint_names:
    - panda_2_joint1
    - panda_2_joint2
    - panda_2_joint3
    - panda_2_joint4
    - panda_2_joint5
    - panda_2_joint6
    - panda_2_joint7
  # Configure the threshold angle for printing joint limit warnings.
  joint_limit_warning_threshold: 0.1 # [rad]
  # Activate rate limiter? [true|false]
  rate_limiting: true
  # Cutoff frequency of the low-pass filter. Set to >= 1000 to deactivate.
  cutoff_frequency: 1000
  # Internal controller for motion generators [joint_impedance|cartesian_impedance]
  internal_controller: joint_impedance
  # Configure the initial defaults for the collision behavior reflexes.
```

```
  collision_config:
    lower_torque_thresholds_acceleration: [20.0, 20.0, 18.0, 18.0, 16.0, 14.0, 12.0]  # [Nm]
    upper_torque_thresholds_acceleration: [20.0, 20.0, 18.0, 18.0, 16.0, 14.0, 12.0]  # [Nm]
    lower_torque_thresholds_nominal: [20.0, 20.0, 18.0, 18.0, 16.0, 14.0, 12.0]  # [Nm]
    upper_torque_thresholds_nominal: [20.0, 20.0, 18.0, 18.0, 16.0, 14.0, 12.0]  # [Nm]
    lower_force_thresholds_acceleration: [20.0, 20.0, 20.0, 25.0, 25.0, 25.0]  # [N, N, N, Nm, Nm, Nm]
    upper_force_thresholds_acceleration: [20.0, 20.0, 20.0, 25.0, 25.0, 25.0]  # [N, N, N, Nm, Nm, Nm]
    lower_force_thresholds_nominal: [20.0, 20.0, 20.0, 25.0, 25.0, 25.0]  # [N, N, N, Nm, Nm, Nm]
    upper_force_thresholds_nominal: [20.0, 20.0, 20.0, 25.0, 25.0, 25.0]  # [N, N, N, Nm, Nm, Nm]

# (+ more robots ...)
```

Note

Be sure to choose unique and consistent `arm_id` parameters. The IDs must match the prefixes in the joint names and should be according to the robot description loaded to the control node's namespace.

For more information on the parameter based loading of hardware classes, please refer to the official documentation of `combined_robot_hw::CombinedRobotHW` from https://github.com/ros-controls/ros_control.

A second important parameter file (see franka_ros/franka_control/config/default_combined_controllers.yaml as a reference) configures a set of default controllers that can be started with the hardware node. The controllers have to match the launched hardware. The provided default parameterization (here for 2 robots) looks like:

```yaml
panda_1_state_controller:
  type: franka_control/FrankaStateController
  arm_id: panda_1
  joint_names:
    - panda_1_joint1
    - panda_1_joint2
    - panda_1_joint3
    - panda_1_joint4
    - panda_1_joint5
    - panda_1_joint6
    - panda_1_joint7
  publish_rate: 30  # [Hz]

panda_2_state_controller:
  type: franka_control/FrankaStateController
  arm_id: panda_2
  joint_names:
    - panda_2_joint1
    - panda_2_joint2
    - panda_2_joint3
    - panda_2_joint4
    - panda_2_joint5
    - panda_2_joint6
    - panda_2_joint7
  publish_rate: 30  # [Hz]

# (+ more controllers ...)
```

We provide a launch file to run the `franka_combined_control_node` with user specified configuration files for hardware and controllers which default to a configuration with 2 robots. Launch it with:

```
roslaunch franka_control franka_combined_control.launch \
    robot_ips:=<your_robot_ips_as_a_map>                 # mandatory
    robot:=<path_to_your_robot_description> \
    args:=<xacro_args_passed_to_the_robot_description> \ # if needed
    robot_id:=<name_of_your_multi_robot_setup> \
    hw_config_file:=<path_to_your_hw_config_file>\       # includes the robot ips!
    controllers_file:=<path_to_your_default_controller_parameterization>\
    controllers_to_start:=<list_of_default_controllers_to_start>\
    joint_states_source_list:=<list_of_sources_to_fuse_a_complete_joint_states_topic>
```

This launch file can be parameterized to run an arbitrary number of robots. To do so just write your own configuration files in the style of franka_control/config/franka_combined_control_node.yaml and franka_ros/franka_control/config/default_combined_controllers.yaml.

Important

Be sure to pass the correct IPs of your robots to *franka_combined_control.launch* as a map. This looks like: *{<arm_id_1>/robot_ip: <my_ip_1>, <arm_id_2>/robot_ip: <my_ip_2>, ...}*

franka_visualization

This package contains publishers that connect to a robot and publish the robot and gripper joint states for visualization in RViz. To run this package launch:

```
roslaunch franka_visualization franka_visualization.launch robot_ip:=<fci-ip> \
  load_gripper:=<true|false> robot:=<panda|fr3>
```

This is purely for visualization - no commands are sent to the robot. It can be useful to check the connection to the robot.

Important

Only one instance of a `franka::Robot` can connect to the robot. This means, that for example the `franka_joint_state_publisher` cannot run in parallel to the `franka_control_node`. This also implies that you cannot execute the visualization example alongside a separate program running a controller.

franka_example_controllers

In this package a set of example controllers for controlling the robot via ROS are implemented. The controllers depict the variety of interfaces offered by the `franka_hw::FrankaHW` class and the according usage. Each example comes with a separate stand-alone launch file that starts the controller on the robot and visualizes it.

To launch the joint impedance example, execute the following command:

```
roslaunch franka_example_controllers joint_impedance_example_controller.launch \
  robot_ip:=<fci-ip> load_gripper:=<true|false> robot:=<panda|fr3>
```

Other single Panda examples are started in the same way.

The `dual_arm_cartesian_impedance_example_controller` showcases the control of two Panda robots based on `FrankaCombinedHW` using one realtime controller for fulfilling Cartesian tasks with an impedance-based control approach. The example controller can be launched with

```
roslaunch franka_example_controllers \
    dual_arm_cartesian_impedance_example_controller.launch \
    robot_id:=<name_of_the_2_arm_setup> \
    robot_ips:=<your_robot_ips_as_a_map> \
    rviz:=<true/false> rqt:=<true/false>
```

The example assumes a robot configuration according to *dual_panda_example.urdf.xacro* where two Pandas are mounted at 1 meter distance on top of a box. Feel free to replace this robot description with one that matches your setup. The option *rviz* allows to choose whether a visualization should be launched. With *rqt* the user can choose to launch an rqt-gui which allows an online adaption of the rendered end-effector impedances at runtime via dynamic reconfigure.

franka_gazebo

This package allows you to simulate our robot in Gazebo. This is possible because Gazebo is able to integrate into the ROS control framework with the gazebo_ros package.

Important

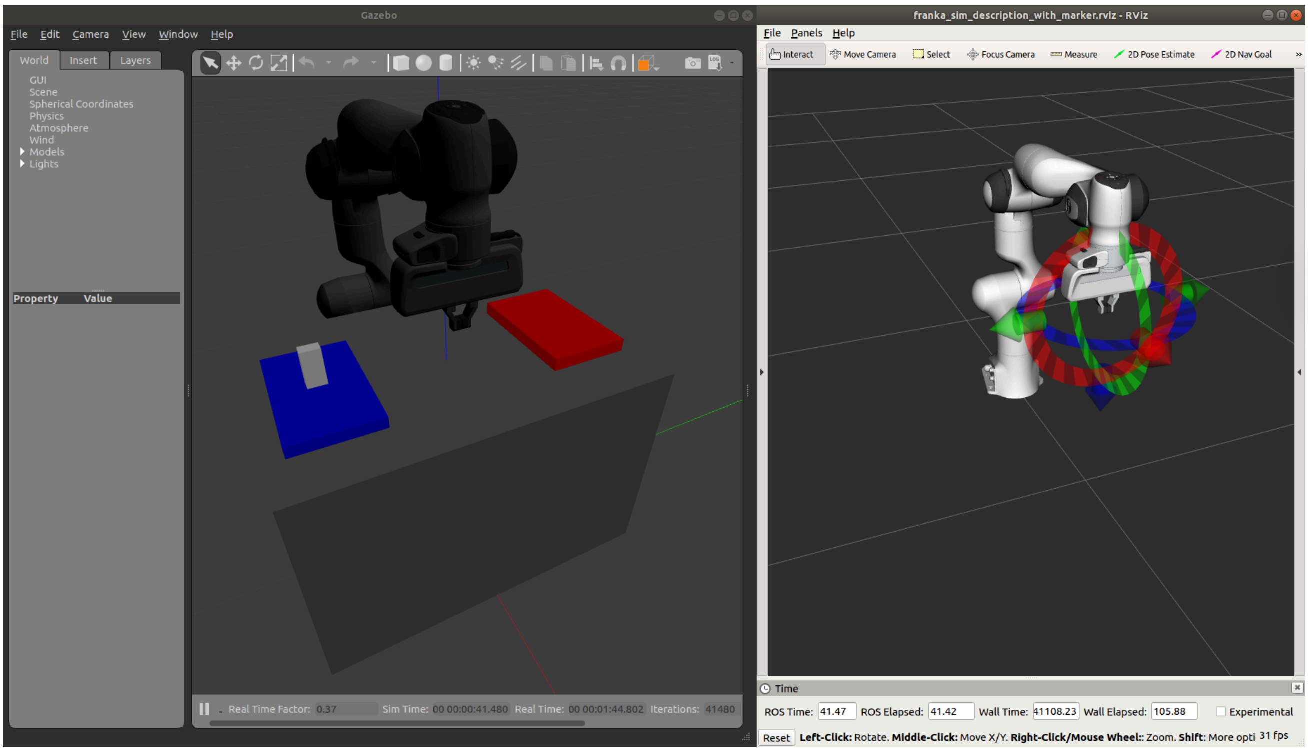
This package is available from 0.8.0

Pick & Place Example

Let's dive in and simulate transporting a stone from A to B. Run the following command to start Gazebo with a Panda and an example world.

```
roslaunch franka_gazebo panda.launch x:=-0.5 \
    world:=$(rospack find franka_gazebo)/world/stone.sdf \
    controller:=cartesian_impedance_example_controller \
    rviz:=true
```

This will bring up the Gazebo GUI where you see the environment with the stone and RViz with which you can control the end-effector pose of the robot.



Gazebo GUI (left) and RViz (right) of the pick and place example

To open the gripper, simply send a goal to the `move` action, similar to how the real `franka_gripper` works. Let's move the gripper to a width of $8\ cm$ between the fingers with $10\ \frac{cm}{s}$:

```
rostopic pub --once /franka_gripper/move/goal franka_gripper/MoveActionGoal "goal: {
width: 0.08, speed: 0.1 }"
```

Since we launched our robot with the Cartesian Impedance controller from franka_example_controllers, we can move the end-effector around, just like in reality, with the interactive marker gizmo in RViz. Move the robot such that the white stone is between the fingers of the gripper ready to be picked up.

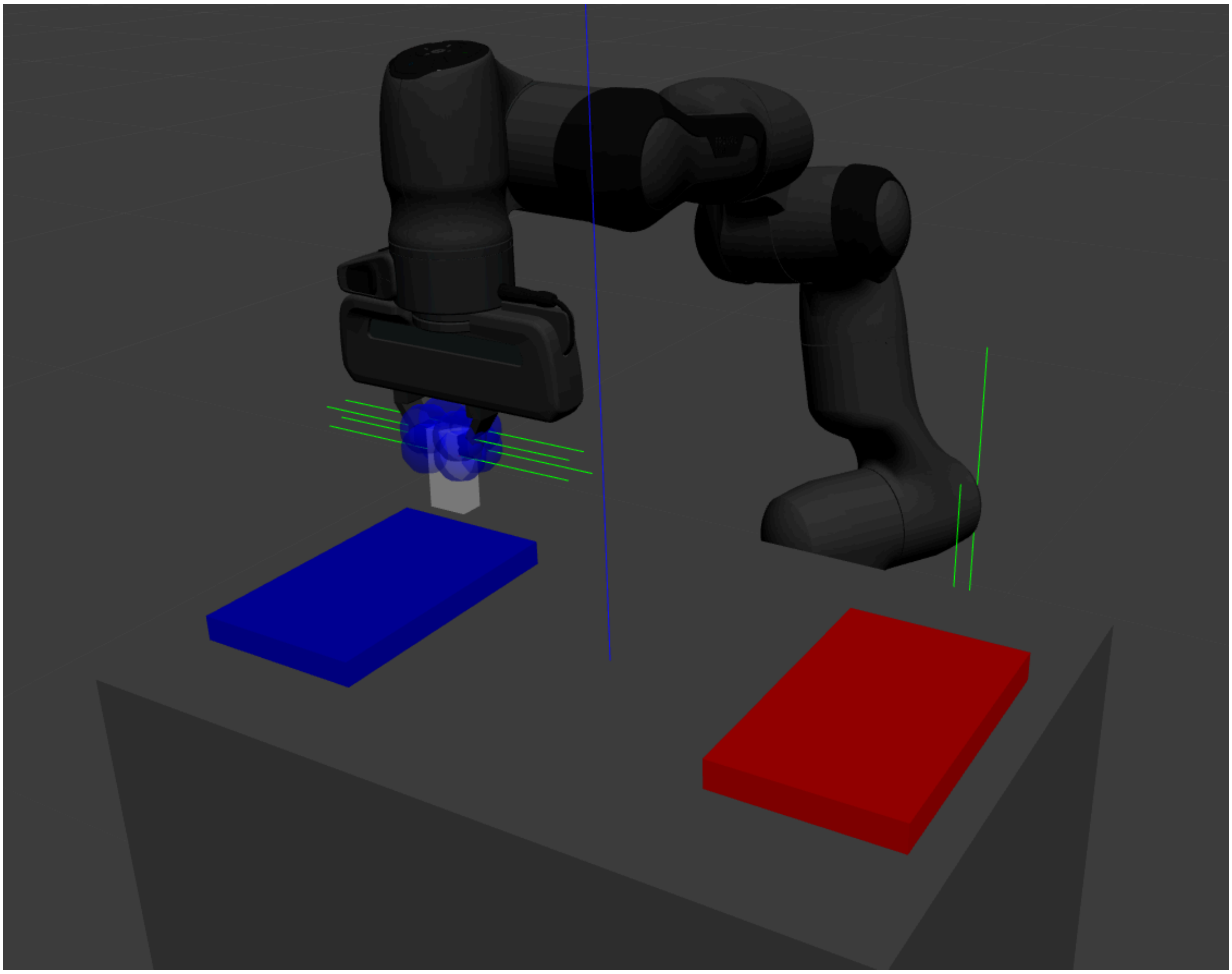
> **Note**
>
> If the robot moves strangely with the elbow, this is because the default nullspace stiffness of the cartesian impedance example controller is set to low. Launch Dynamic Reconfigure and adjust `panda` > `cartesian_impedance_example_controller` > `nullspace_stiffness` if necessary.

To pick up the object, we use the `grasp` action this time, since we want to excerpt a force after the grasp to not drop the object. The stone is around $3\ cm$ wide and $50\ g$ heavy. Let's grasp it with $5\ N$:

```
rostopic pub --once /franka_gripper/grasp/goal \
             franka_gripper/GraspActionGoal \
             "goal: { width: 0.03, epsilon:{ inner: 0.005, outer: 0.005 }, speed: 0.1,
force: 5.0}"
```

> **Note**
>
> In top menu of Gazebo go to **View** > **Contacts** to visualize contact points and forces

If the grasp succeeded, the fingers will now hold the stone in place. If not, probably the goal tolerances (inner and outer epsilon) were too small and the action failed. Now move the object gently over to the red dropoff area.



Transport the stone from blue to red

After you placed it gently on the red pad, stop the grasp with the `stop` action from the gripper:

```
rostopic pub --once /franka_gripper/stop/goal franka_gripper/StopActionGoal {}
```

Note that the contact forces disappear now, since no force is applied anymore. Alternatively you can also use the `move` action.

Customization

The launch file from `franka_gazebo` takes a lot of arguments with which you can customize the behavior of the simulation. For example to spawn two pandas in one simulation you can use the following:

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

  <include file="$(find gazebo_ros)/launch/empty_world.launch" >
    <!-- Start paused, simulation will be started, when Pandas were loaded -->
    <arg name="paused" value="true"/>
    <arg name="use_sim_time" value="true"/>
  </include>

  <group ns="panda_1">
    <include file="$(find franka_gazebo)/launch/panda.launch">
      <arg name="arm_id"     value="panda_1" />
      <arg name="y"          value="-0.5" />
      <arg name="controller" value="cartesian_impedance_example_controller" />
      <arg name="rviz"       value="false" />
      <arg name="gazebo"     value="false" />
      <arg name="paused"     value="true" />
    </include>
  </group>

  <group ns="panda_2">
    <include file="$(find franka_gazebo)/launch/panda.launch">
      <arg name="arm_id"     value="panda_2" />
      <arg name="y"          value="0.5" />
      <arg name="controller" value="force_example_controller" />
      <arg name="rviz"       value="false" />
      <arg name="gazebo"     value="false" />
      <arg name="paused"     value="false" />
    </include>
  </group>

</launch>
```

Note

To see which arguments are supported use: `roslaunch franka_gazebo panda.launch --ros-args`

FrankaHWSim

By default Gazebo ROS can only simulate joints with “standard” hardware interfaces like *Joint State Interfaces* and *Joint Command Interfaces*. However our robot is quite different from this architecture! Next to these joint-specific interfaces it also supports **robot-specific** interfaces like the `FrankaModelInterface` (see franka_hw). Naturally gazebo does not understand these custom hardware interfaces by default. This is where the `FrankaHWSim` plugin comes in.

To make your robot capable of supporting Franka interfaces, simply declare a custom `robotSimType` in your URDF:

```xml
<gazebo>
  <plugin name="gazebo_ros_control" filename="libgazebo_ros_control.so">
    <robotNamespace>${arm_id}</robotNamespace>
    <controlPeriod>0.001</controlPeriod>
    <robotSimType>franka_gazebo/FrankaHWSim</robotSimType>
  </plugin>
  <self_collide>true</self_collide>
</gazebo>
```

When you spawn this robot with the model spawner this plugin will be loaded into the gazebo node. It will scan your URDF and try to find supported hardware interfaces. Up to now only some of the interfaces provided by franka_hw are supported:

	Interface	Function
✔	`hardware_interface::JointStateInterface`	Reads joint states.
✔	`hardware_interface::EffortJointInterface`	Commands joint-level torques and reads joint states.
✔	`hardware_interface::VelocityJointInterface`	Commands joint velocities and reads joint states.
✔	`hardware_interface::PositionJointInterface`	Commands joint positions and reads joint states.
✔	`franka_hw::FrankaStateInterface`	Reads the full robot state.
✔	`franka_hw::FrankaModelInterface`	Reads the dynamic and kinematic model of the robot.
✘	`franka_hw::FrankaPoseCartesianInterface`	Commands Cartesian poses and reads the full robot state.
✘	`franka_hw::FrankaVelocityCartesianInterface`	Commands Cartesian velocities and reads the full robot state.

Important

This implies that you can only simulate controllers, that claim these supported interfaces and none other! For example the Cartesian Impedance Example Controller can be simulated, because it only requires the `EffortJoint`-, `FrankaState`- and `FrankaModelInterface`. However the Joint Impedance Example Controller can't be simulated, because it requires the `FrankaPoseCartesianInterface` which is not supported yet.

Next to the realtime hardware interfaces the `FrankaHWSim` plugin supports some of the non-realtime commands that franka_control supports:

	Service / Type	Explanation
✘	`set_joint_impedance` / SetJointImpedance	Gazebo does not simulate an internal impedance controller, but sets commanded torques directly
✘	`set_cartesian_impedance` / SetCartesianImpedance	Gazebo does not simulate an internal impedance controller, but sets commanded torques directly
✔	`set_EE_frame` / SetEEFrame	Sets the ${}^{\mathrm{NE}}\mathbf{T}_{\mathrm{EE}}$ i.e. the homogenous transformation from nominal end-effector to end-effector. You can also initialize this by setting the ROS parameter `/<arm_id>/NE_T_EE`. Normally you would set ${}^{\mathrm{F}}\mathbf{T}_{\mathrm{NE}}$ in Desk, but in `franka_gazebo` it's assumed as identity if no gripper was specified or defines a rotation around Z by $45\,^{\circ}$ and an offset by $10.34\,cm$ (same as Desk for the hand). You can always overwrite this value by setting the ROS parameter `/<arm_id>/NE_T_EE` manually.
✔	`set_K_frame` / SetKFrame	Sets the ${}^{\mathrm{EE}}\mathbf{T}_{\mathrm{K}}$ i.e. the homogenous transformation from end-effector to stiffness frame.
✔	`set_force_torque_collision_behavior` / SetForceTorqueCollisionBehavior	Sets thresholds above which external wrenches are treated as contacts and collisions.
✘	`set_full_collision_behavior` / SetFullCollisionBehavior	Not yet implemented
✔	`set_load` / SetLoad	Sets an external load to compensate its gravity for, e.g. of a grasped object. You can also initialize this by setting the ROS parameters `/<arm_id>/{m_load,I_load,F_x_load}` for mass, inertia tensor and center of mass for the load, respectively.
✔	`set_user_stop` / std_srvs::SetBool (since 0.9.1)	This is a special service only available in `franka_gazebo` to simulate the user stop. Pressing the user stop (a.k.a publishing a `true` via this service) will *disconnect* all command signals from ROS controllers to be fed to the joints. To connect them again call the `error_recovery` action.

FrankaGripperSim

This plugin simulates the franka_gripper_node in Gazebo. This is done as a ROS controller for the two finger joints with a position & force controller. It offers the same five actions like the real gripper node:

- `/<arm_id>/franka_gripper/homing`
- `/<arm_id>/franka_gripper/stop`
- `/<arm_id>/franka_gripper/move`
- `/<arm_id>/franka_gripper/grasp`
- `/<arm_id>/franka_gripper/gripper_action`

Important

The `grasp` action has a bug, that it will not succeed nor abort if the target width lets the fingers **open**. This is because of missing the joint limits interface which lets the finger oscillate at their limits. For now only use the `grasp` action to *close* the fingers!

It is assumed that the URDF contains two finger joints which can be force controlled, i.e. have a corresponding `EffortJointInterface` transmission declared. This controller expects the following parameters in its namespace:

- `type` (string, required): Should be `franka_gazebo/FrankaGripperSim`
- `arm_id` (string, required): The arm id of the panda, to infer the name of the finger joints
- `finger1/gains/p` (double, required): The proportional gain for the position-force controller of the first finger
- `finger1/gains/i` (double, default: 0): The integral gain for the position-force controller of the first finger
- `finger1/gains/d` (double, default: 0): The differential gain for the position-force controller of the first finger
- `finger2/gains/p` (double, required): The proportional gain for the position-force controller of the second finger
- `finger2/gains/i` (double, default: 0): The integral gain for the position-force controller of the second finger
- `finger2/gains/d` (double, default: 0): The differential gain for the position-force controller of the second finger
- `move/width_tolerance` (double, default $5\ mm$): The move action succeeds, when the finger width becomes below this threshold
- `grasp/resting_threshold` (double, default $1\ \frac{mm}{s}$): Below which speed the target width should be checked to abort or succeed the grasp action
- `grasp/consecutive_samples` (double, default: 3): How many times the speed has to be consecutively below `resting_threshold` before the grasping will be evaluated
- `gripper_action/width_tolerance` (double, default $5\ mm$): The gripper action succeeds, when the finger width becomes below this threshold
- `gripper_action/speed` (double, default $10\ \frac{cm}{s}$): The speed to use during the gripper action

JointStateInterface

To be able to access the joint state interface from a ROS controller you only have to declare the corresponding joint in any transmission tag in the URDF. Then a joint state interface will be automatically available. Usually you declare transmission tags for command interfaces like the EffortJointInterface.

Note

For any joint named `<arm_id>_jointN` (with N as integer) FrankaHWSim will automatically compensate its gravity to mimic the behavior of libfranka.

EffortJointInterface

To be able to send effort commands from your controller to a joint, you simply declare a transmission tag for the joint in your URDF with the corresponding hardware interface type:

```
<transmission name="${joint}_transmission">
 <type>transmission_interface/SimpleTransmission</type>
 <joint name="${joint}">
   <hardwareInterface>hardware_interface/EffortJointInterface</hardwareInterface>
 </joint>
 <actuator name="${joint}_motor">
   <hardwareInterface>${transmission}</hardwareInterface>
 </actuator>
</transmission>

<gazebo reference="${joint}">
  <!-- Needed for ODE to output external wrenches on joints -->
  <provideFeedback>true</provideFeedback>
</gazebo>
```

Note

If you want to be able to read external forces or torques, which come e.g. from collisions, make sure to set the `<provideFeedback>` tag to `true`.

FrankaStateInterface

This is a **robot-specific** interface and thus a bit different from the normal hardware interfaces. To be able to access the franka state interface from your controller declare the following transmission tag with all seven joints in your URDF:

```xml
<transmission name="${arm_id}_franka_state">
  <type>franka_hw/FrankaStateInterface</type>
  <joint name="${arm_id}_joint1">
<hardwareInterface>franka_hw/FrankaStateInterface</hardwareInterface></joint>
  <joint name="${arm_id}_joint2">
<hardwareInterface>franka_hw/FrankaStateInterface</hardwareInterface></joint>
  <joint name="${arm_id}_joint3">
<hardwareInterface>franka_hw/FrankaStateInterface</hardwareInterface></joint>
  <joint name="${arm_id}_joint4">
<hardwareInterface>franka_hw/FrankaStateInterface</hardwareInterface></joint>
  <joint name="${arm_id}_joint5">
<hardwareInterface>franka_hw/FrankaStateInterface</hardwareInterface></joint>
  <joint name="${arm_id}_joint6">
<hardwareInterface>franka_hw/FrankaStateInterface</hardwareInterface></joint>
  <joint name="${arm_id}_joint7">
<hardwareInterface>franka_hw/FrankaStateInterface</hardwareInterface></joint>

  <actuator name="${arm_id}_motor1">
<hardwareInterface>franka_hw/FrankaStateInterface</hardwareInterface></actuator>
  <actuator name="${arm_id}_motor2">
<hardwareInterface>franka_hw/FrankaStateInterface</hardwareInterface></actuator>
  <actuator name="${arm_id}_motor3">
<hardwareInterface>franka_hw/FrankaStateInterface</hardwareInterface></actuator>
  <actuator name="${arm_id}_motor4">
<hardwareInterface>franka_hw/FrankaStateInterface</hardwareInterface></actuator>
  <actuator name="${arm_id}_motor5">
<hardwareInterface>franka_hw/FrankaStateInterface</hardwareInterface></actuator>
  <actuator name="${arm_id}_motor6">
<hardwareInterface>franka_hw/FrankaStateInterface</hardwareInterface></actuator>
  <actuator name="${arm_id}_motor7">
<hardwareInterface>franka_hw/FrankaStateInterface</hardwareInterface></actuator>
</transmission>
```

When your controller accesses the RobotState via the `FrankaStateInterface` it can expect the following values to be simulated:

	Field	Comment
✔	`O_T_EE`	
✘	`O_T_EE_d`	Motion generation not yet supported, field will contain only zeros
✔	`F_T_EE`	Can be configured via parameters `F_T_NE`, `NE_T_EE` and/or service calls to `set_EE_frame`
✔	`NE_T_EE`	Can be configured via parameter `NE_T_EE` and/or service calls to `set_EE_frame`
✔	`EE_T_K`	Can be configured via parameter `EE_T_K` and/or service calls to `set_K_frame`
✔	`m_ee`	Will be set from the mass in the inertial tag of URDF, if a hand can be found, otherwise zero. Can be overwritten by parameter `m_ee`
✔	`I_ee`	Will be set from the inertia in the inertial tag of URDF, if a hand be found, otherwise zero. Can be overwritten by parameter `I_ee`

	Field	Comment
✔	`F_x_Cee`	Will be set from the origin in the inertial tag of URDF, if a hand can be found, otherwise zero. Can be overwritten by parameter `F_x_Cee`
✔	`m_load`	Can be configured via parameter `m_load` and/or service calls to `set_load`
✔	`I_load`	Can be configured via parameter `I_load` and/or service calls to `set_load`
✔	`F_x_Cload`	Can be configured via parameter `F_x_Cload` and/or service calls to `set_load`
✔	`m_total`	
✔	`I_total`	
✔	`F_x_Ctotal`	
✘	`elbow`	
✘	`elbow_d`	
✘	`elbow_c`	
✘	`delbow_d`	
✘	`delbow_c`	
✔	`tau_J`	Comes directly from Gazebo
✔	`tau_J_d`	The values send by your effort controller. Zero otherwise.
✔	`dtau_J`	Numerical derivative of `tau_J`
✔	`q`	Comes directly from Gazebo
✔	`q_d`	The last commanded joint position when using the position interface. Same as `q` when using the velocity interface. However, the value will not be updated when using the effort interface.
✔	`dq`	Comes directly from Gazebo
✔	`dq_d`	The last commanded joint velocity when using the velocity interface. Same as `dq` when using the position interface. However, the value will be zero when using the effort interface.
✔	`ddq_d`	Current acceleration when using the position or velocity interface. However, the value will be zero when using the effort interface.
✔	`joint_contact`	$\mid \hat{\tau}_{ext} \mid > \mathrm{thresh}_{lower}$ where the threshold can be set by calling `set_force_torque_collision_behavior`
✔	`joint_collision`	$\mid \hat{\tau}_{ext} \mid > \mathrm{thresh}_{upper}$ where the threshold can be set by calling `set_force_torque_collision_behavior`

	Field	Comment
✔	`cartesian_contact`	$\mid {}^K\hat{F}_{K,ext} \mid > \mathrm{thresh}_{lower}$ where threshold can be set by calling `set_force_torque_collision_behavior`
✔	`cartesian_collision`	$\mid {}^K\hat{F}_{K,ext} \mid > \mathrm{thresh}_{upper}$ where threshold can be set by calling `set_force_torque_collision_behavior`
✔	`tau_ext_hat_filtered`	$\hat{\tau}_{ext}$ i.e. estimated external torques and forces at the end-effector, filtered with a exponential moving average filter (EMA). This filtering α can be configured via a ROS parameter. This field does not contain any gravity, i.e. $\tau_{ext} = \tau_J - \tau_{J_d} - \tau_{gravity}$
✔	`O_F_ext_hat_K`	${}^O\hat{F}_{K,ext} = J_O^{\top+} \cdot \hat{\tau}_{ext}$
✔	`K_F_ext_hat_K`	${}^K\hat{F}_{K,ext} = J_K^{\top+} \cdot \hat{\tau}_{ext}$
✘	`O_dP_EE_d`	
✔	`O_ddP_O`	Will be the same as the `gravity_vector` ROS parameter. By default it is {0,0,-9.8}
✘	`O_T_EE_c`	
✘	`O_dP_EE_c`	
✘	`O_ddP_EE_c`	
✔	`theta`	Same as `q`, since we don't simulate soft joints in Gazebo
✔	`dtheta`	Same as `dq`, since we don't simulate soft joints in Gazebo
✘	`current_errors`	Will entirely be false, reflex system not yet implemented
✘	`last_motion_errors`	Will entirely be false, reflex system not yet implemented
✔	`control_command_success_rate`	Always 1.0
✘	`robot_mode`	Robot mode switches and reflex system not yet implemented
✔	`time`	Current ROS time in simulation, comes from Gazebo

FrankaModelInterface

This is a **robot-specific** interface and thus a bit different from the normal hardware interfaces. To be able to access the franka model interface from your controller declare the following transmission tag with the root (e.g. `panda_joint1`) and the tip (e.g. `panda_joint8`) of your kinematic chain in your URDF:

```
<transmission name="${arm_id}_franka_model">
  <type>franka_hw/FrankaModelInterface</type>
  <joint name="${root}">
    <role>root</role>
    <hardwareInterface>franka_hw/FrankaModelInterface</hardwareInterface>
  </joint>
  <joint name="${tip}">
    <role>tip</role>
    <hardwareInterface>franka_hw/FrankaModelInterface</hardwareInterface>
  </joint>

  <actuator name="${root}_motor_root">
<hardwareInterface>franka_hw/FrankaModelInterface</hardwareInterface></actuator>
  <actuator name="${tip}_motor_tip"  >
<hardwareInterface>franka_hw/FrankaModelInterface</hardwareInterface></actuator>
</transmission>
```

The model functions themselve are implemented with KDL. This takes the kinematic structure and the inertial properties from the URDF to calculate model properties like the Jacobian or the mass matrix.

Friction

For objects to have proper friction between each other (like fingers and objects) you need to tune some Gazebo parameters in your URDF. For the links `panda_finger_joint1` and `panda_finger_joint2` we recommend to set the following parameters:

```
<gazebo reference="${link}">
  <collision>
    <max_contacts>10</max_contacts>
    <surface>
      <contact>
        <ode>
          <!-- These two parameter need application specific tuning. -->
          <!-- Usually you want no "snap out" velocity and a generous -->
          <!-- penetration depth to keep the grasping stable -->
          <max_vel>0</max_vel>
          <min_depth>0.003</min_depth>
        </ode>
      </contact>
      <friction>
        <ode>
          <!-- Rubber/Rubber contact -->
          <mu>1.16</mu>
          <mu2>1.16</mu2>
        </ode>
      </friction>
      <bounce/>
    </surface>
  </collision>
</gazebo>
```

Note

Refer to Gazebo Friction Documentation

franka_msgs

This package contains message, service and action types that are primarily used the packages `franka_hw` and `franka_control` to publish robot states or to expose the libfranka API in the ROS ecosystem. For more information about the services and actions offered in this package, please refer to franka_control.

panda_moveit_config

Note

This package was moved to the ros_planning repos.

For more details, documentation and tutorials, please have a look at the MoveIt! tutorials website.

Writing your own controller

All example controllers from the example controllers package are derived from the `controller_interface::MultiInterfaceController` class, which allows to claim up to four interfaces in one controller instance. The declaration of your class then looks like:

```
class NameOfYourControllerClass : controller_interface::MultiInterfaceController <
                              my_mandatory_first_interface,
                              my_possible_second_interface,
                              my_possible_third_interface,
                              my_possible_fourth_interface> {
  bool init (hardware_interface::RobotHW* hw, ros::NodeHandle& nh);  // mandatory
  void update (const ros::Time& time, const ros::Duration& period);  // mandatory
  void starting (const ros::Time& time)   // optional
  void stopping (const ros::Time& time);  // optional
  ...
}
```

The available interfaces are described in Section franka_hw.

Important

Note that the claimable combinations of commanding interfaces are restricted as it does not make sense to e.g. command joint positions and Cartesian poses simultaneously. Read-only interfaces like the *JointStateInterface*, the *FrankaStateInterface* or the *FrankaModelInterface* can always be claimed and are not subject to restrictions.

Possible claims to command interfaces are:

`franka_hw::FrankaHW`	`franka_combinable_hw::FrankaCombinableHW`
• all possible single interface claims • `EffortJointInterface` + `PositionJointInterface` • `EffortJointInterface` + `VelocityJointInterface` • `EffortJointInterface` + `FrankaCartesianPoseInterface` • `EffortJointInterface` + `FrankaCartesianVelocityInterface`	• `EffortJointInterface` • `EffortJointInterface` + `FrankaCartesianPoseInterface` • `EffortJointInterface` + `FrankaCartesianVelocityInterface`

The idea behind offering the *EffortJointInterface* in combination with a motion generator interface is to expose the internal motion generators to the user. The calculated desired joint pose corresponding to a motion generator command is available in the robot state one time step later. One use case for this combination would be following a Cartesian trajectory using your own joint-level torque controller. In this case you would claim the combination *EffortJointInterface* + *FrankaCartesianPoseInterface*, stream your trajectory into the *FrankaCartesianPoseInterface*, and compute your joint-level torque commands based on the resulting desired joint pose (q_d) from the robot state. This allows to use the robot's built-in inverse kinematics instead of having to solve it on your own.

To implement a fully functional controller you have to implement at least the inherited virtual functions `init` and `update`. Initializing - e.g. start poses - should be done in the `starting` function as `starting` is called when restarting the controller, while `init` is called only once when loading the controller. The `stopping` method should contain shutdown related functionality (if needed).

> **Important**
>
> Always command a gentle slowdown before shutting down the controller. When using velocity interfaces, do not simply command zero velocity in `stopping`. Since it might be called while the robot is still moving, it would be equivalent to commanding a jump in velocity leading to very high resulting joint-level torques. In this case it would be better to keep the same velocity and stop the controller than sending zeros and let the robot handle the slowdown.

Your controller class must be exported correctly with `pluginlib` which requires adding:

```cpp
#include <pluginlib/class_list_macros.h>
// Implementation ..
PLUGINLIB_EXPORT_CLASS(name_of_your_controller_package::NameOfYourControllerClass,
                       controller_interface::ControllerBase)
```

at the end of the `.cpp` file. In addition you need to define a `plugin.xml` file with the following content:

```xml
<library path="lib/lib<name_of_your_controller_library>">
  <class name="name_of_your_controller_package/NameOfYourControllerClass"
         type="name_of_your_controller_package::NameOfYourControllerClass"
         base_class_type="controller_interface::ControllerBase">
    <description>
      Some text to describe what your controller is doing
    </description>
  </class>
</library>
```

which is exported by adding:

```xml
<export>
  <controller_interface plugin="${prefix}/plugin.xml"/>
</export>
```

to your package.xml. Further, you need to load at least a controller name in combination with a controller type to the ROS parameter server. Additionally, you can include other parameters you need. An exemplary configuration.yaml file can look like:

```yaml
your_custom_controller_name:
  type: name_of_your_controller_package/NameOfYourControllerClass
  additional_example_parameter: 0.0
  # ..
```

Now you can start your controller using the `controller_spawner` node from ROS control or via the service calls offered by the `hardware_manager`. Just make sure that both the `controller_spawner` and the `franka_control_node` run in the same namespace. For more details have a look at the controllers from the franka_example_controllers package or the ROS control tutorials.