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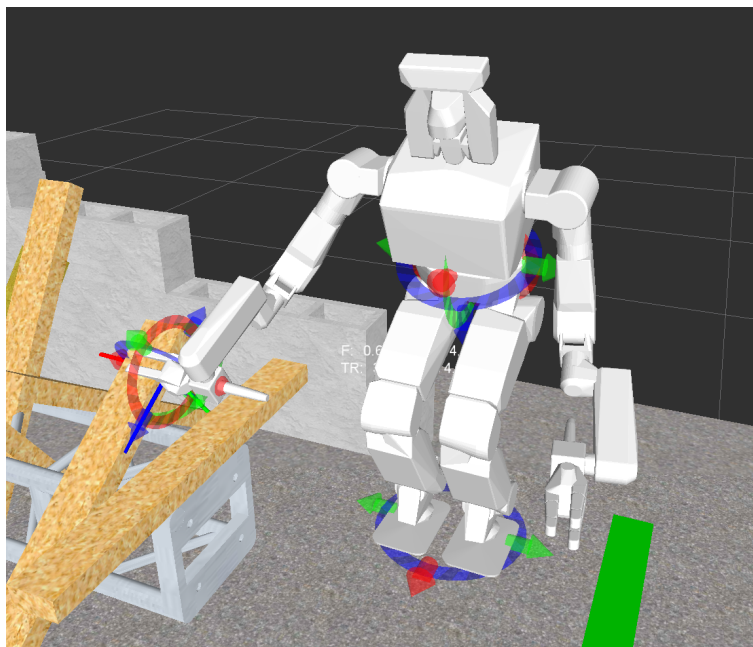
INSTITUTE FOR ROBOTICS & INTELLIGENT MACHINES

HUMANOID ROBOTICS LAB

DRC-HUBO Operation Manual

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Code Repositories

The following code repositories are required in order to execute our tasks using our code. They consist of real-time processes that run on the robot, and code that uses ROS and runs mostly on a local computer.

Main Code

Code repositories that run in real-time on the robot.

- hubo_gt
 - https://github.com/golems/hubo_gt (develop)

Major Dependencies(To Do: check forked repos)

- <https://github.com/golems/hubo-ach> (master, installation required)
- https://github.com/calderpg/dynamixel_motor (master)
- https://github.com/hubo/hubo_planning_common (master)
- https://github.com/golems/hubo_vision_common (catkinize)
- https://github.com/golems/hubo_ros_core (master)
- https://github.com/golems/hubo_ros_control (master)
- https://github.com/golems/hubo_head_description (master)
- https://github.com/golems/teleop_toolkit (master)

Minor Dependencies

Dependencies that can be install with *apt-get install*

- ach-utils
- autoconf, automake, autoconf-archive, libtool
- expat
- freeglut3-dev
- libboost1.46-dev
- libeigen3-dev
- libreadline6-dev

- `ros-groovy-desktop-full` (note. catkin workspace & env. set-up required)
- `ros-groovy-control-msgs`
- `ros-groovy-libccd`
- `ros-groovy-moveit-msgs`
- `ros-groovy-spacnav-node`
- `ros-groovy-urdf`
- `ros-groovy-urdfdom`
- `libopenni2-dev`

Vision

- https://github.com/ros-drivers/openni2_camera (groovy-devel)
- https://github.com/ros-drivers/openni2_launch (groovy-devel)

System Setup

This section describes how to get everything on the operators computer up and running with RViz.

RViz Setup

1. After successfully running *catkin_make* launch *roscore* by typing the following command into the terminal.

```
roscore
```

2. Then in a second terminal start your RViz session with

```
roslaunch rviz rviz
```

Operation Instructions

This section details how to operate DRC-HUBO from the initialization phase to execution of the tasks. The different phases include *Starting-up HUBO*, *Starting-up Perception*, *Walking*, and *Teleop Manipulation*.

Starting-up HUBO

This section describes how to start-up HUBO.

1. Make sure your computer is connected to the local Humanoids router via Ethernet or to the **humanoids** or **humanoids-5** wireless network.
2. Turn on motor controllers with remote
3. Connect to HUBO's computer using ssh.

```
$ ssh hubo@hubo-ach-beta-1
      (Note: password: hubo1234)
```

4. **IMPORTANT:** Turn on power to the motor control boards before starting the daemons
5. Now start the daemons from the ssh session connected to HUBO's computer

```
$ ssh sudo service hubo-motion teleop
```

6. On your local computer (outside of the ssh session), start a ROS master, launch RViz, start the state publisher and the fullbody_teleop nodes.

```
$ roscore (Terminal 1)
$ rosrn rviz rviz (Terminal 2)
$ roslaunch hubo_motion_ros hubo_state.launch (Terminal 3)
$ roslaunch hubo_motion_ros fullbody_teleop.launch (Terminal 4)
```

7. Click on the *HuboInitPanel* panel tab.
8. On the **Joint Command** tab ensure "IP Address" is correct.
9. Click "Connect" to send and receive ach channels between HUBO's computer and the remote computer. If it won't connect see the Troubleshooting section.
10. To check if it is indeed connected and receiver ach frames, click on the **Sensor State** tab in HuboInit-Panel and make sure the sensor values are changing. If they are not, then something was most likely done out of order.
11. Make sure HUBO is sufficiently raised above the ground and click "Home All" to home all of HUBO's joints.
12. If any active joints do not home, indicated by the color in the *Joint State* section not being gray, click the "Rehome" button. Button color meanings are

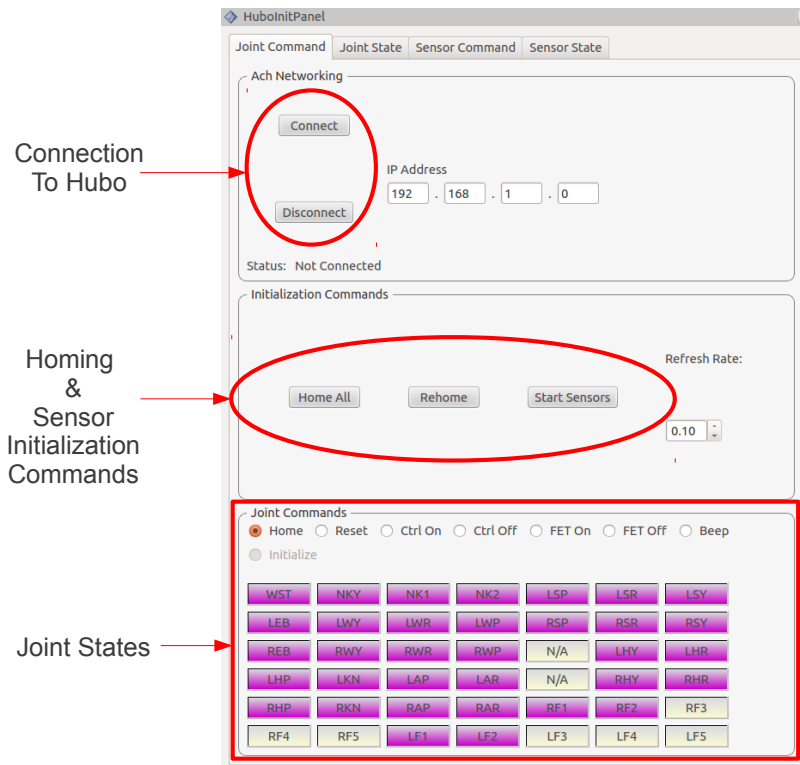


Figure 1: Picture of HUBO_init panel.

- GRAY: homed
- PURPLE: not homed
- RED: error
- WHITE: inactive

13. If any joints won't home, you can do one of two options:

- Click the *Reset* radio button and then click the joint(s) that won't home. Then click the *Home* radio button and click the joint(s) that didn't home. Then press the "Rehome" button again.
- Run "sudo service hubo-motion stop", turn off the motor power, wait a moment, turn it back on, and run "sudo service hubo-motion teleop". Then try homing again from the beginning. If this doesn't work, HUBO's computer needs to be rebooted and you need to start over from step 1. Basically the CAN line gets corrupted if the daemons are started while the power to the motor control boards is off.

14. Once the joints are all homed, press the "Start Sensors" button to initialize the IMU and Force/Torque sensors.

15. Click on the *Sensor State* tab and ensure the sensor values are updating and are reasonable. If they aren't, then restart the whole process.

16. Now you click on the **HuboMotionPanel** tab and click the **Connect** button.

17. Click the **Teleop** button on the top right.

Starting-up Perception

Post DRC-Trials start-up procedure:

```
$ roslaunch hubo_drc_vision hubo_flea3_remote.launch
$ roslaunch hubo_drc_vision hubo_vision_workstation.launch
$ roslaunch hubo_drc_vision hubo_gt_backpack.launch
```

This section is heavily under construction. Generally, what you will need to do is something like this:

```
$ roslaunch hubo_drc_vision hubo_openni.launch
```


Camera Calibration

In many circumstances, you may find that an approximate camera calibration is insufficient for real manipulation tasks. In order to alleviate this problem, the intrinsic and extrinsic properties of the camera need to be computed. For intrinsic calibration, we used the ROS package `camera_calibration` (http://wiki.ros.org/camera_calibration). If using a PrimeSense camera, both the infrared and rgb cameras will need to have their intrinsics calibrated as documented in the package.

For extrinsic calibration, we have written a small subroutine to assist with the calculation. There are several steps:

1. Attach checkerboards to the flat places on the hands. Example checkerboards are provided in the `hubo_gt_ros/hubo_drc_vision/resources` folder.
2. Measure the transform from the hand origin to the checkerboard origin. These values are currently hard-coded for a single checkerboard in the main function of `camera_calib.cpp`; this needs to be expanded to accept ROS parameters.
3. Launch the calibration procedure as follows:

```
$ roslaunch hubo_drc_vision calibrate_camera.launch
```

This will load a list of joint angles from a csv file and play that "trajectory" through the motion pipeline. A second node will monitor the vision system and will compute the least-squares transform that best solves the system of observed and expected points. This transform will be published into TF, and the results can be viewed in RVIZ (use `calibration.rviz` to automatically configure RVIZ to display the relevant topics).

Walking

This section describes how to make HUBO walk. And assumes the robot is already up and running and standing on the ground on two feet.

1. Click on the *HuboWalkPanel* tab.

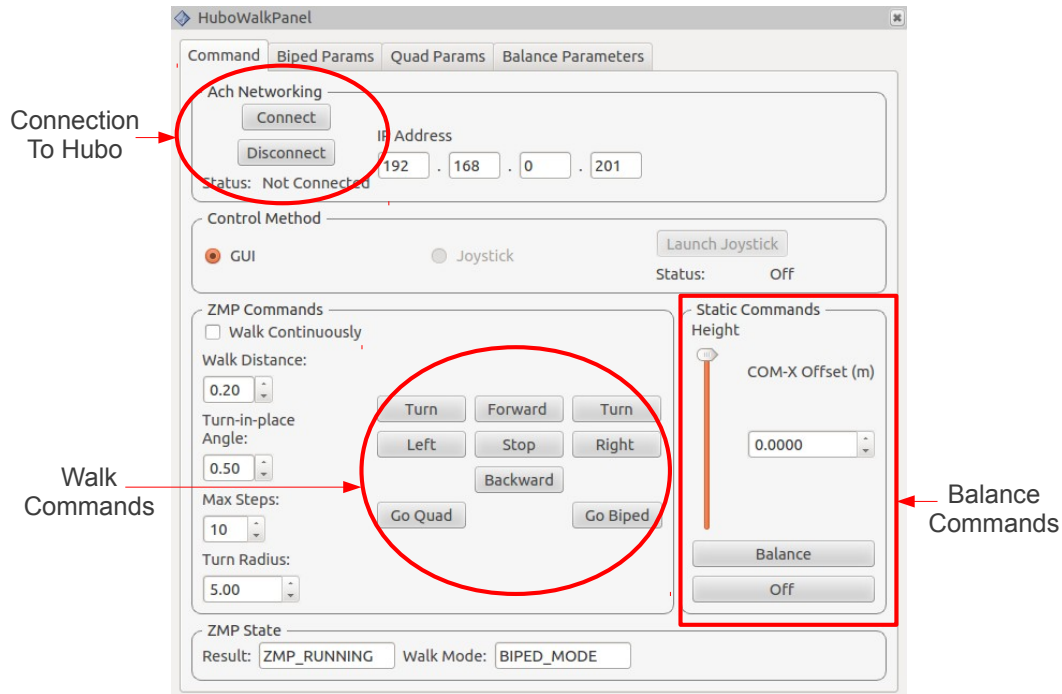


Figure 2: Picture of hubo_walk panel.

2. Ensure the IP Address is correct.
3. Click “Connect” to send and receive ach channels between HUBO’s computer and the remote computer. If it won’t connect see the Troubleshooting section.
4. Based on vision feedback enter desired walk distance, max number of steps, and turn-in-place angle (for turning in place).
5. Click the “Go Quad” button to transition into quadruped mode.
6. Click the walk command desired to get to your desired goal. (Eventually the interface will use a desired location and orientation, and the ZMP walk generator will create a footstep plan to get there.) The *Walk Continuously* checkbox determines whether or not to walk the specified distance or walk until receiving a stop command. The *ZMP State* section at the bottom of the panel display the state of the ZMP walker generator.
7. Click “Go Biped” to get back up on two feet in order to manipulate objects.
8. In the *Balance Commands* section of the panel, click ”Balance” to go into static balancing mode.

9. The x-location of the center of mass can be adjusted in the *COM-X Offset (m)* field. Then click the "Balance" button to send the command.
10. The squat height of the robot can be adjusted by sliding the *Height* slider up and down, which automatically sends the command to the robot.

Manipulation

This section describes how to teleoperate HUBO in order to manipulate objects in the environment with either or both arms. NB: First install all software outlined in Code Repositories

1. If you haven't already, start up ROS

```
$ roscore
$ rosrun rviz rviz
```

Configuring RViz interface

- If the Displays panel is not visible already, click on the Panels menu and click on Displays.
- Under Global Options, set Fixed Frame to /Body_RAP.
- Click Add and scroll to RobotModel. Set topic to robot_description. Set alpha to 0.5. If the model does not appear, uncheck and check the RobotModel checkbox.
- Click Add and scroll to RobotModel. Set topic to robot_planning_description. If the model does not appear, uncheck and check the RobotModel checkbox.
- Click Add and scroll to Pose. Set Topic to /rh_pose. Set Axes Length to 0.1 and Axes Radius to 0.01.
- Click Add and scroll to TF. Set Marker Scale to 0.1.
- Click Add and scroll to InteractiveMarkers. Set Topic to /joint_controls/update.

2. Start the teleoperation interface and state feedback

```
$ roslaunch hubo_motion_ros fullbody_teleop.launch
$ roslaunch hubo_motion_ros hubo_state.launch
```

3. (Optional) Start up Vision system as discussed in Starting-up Perception.

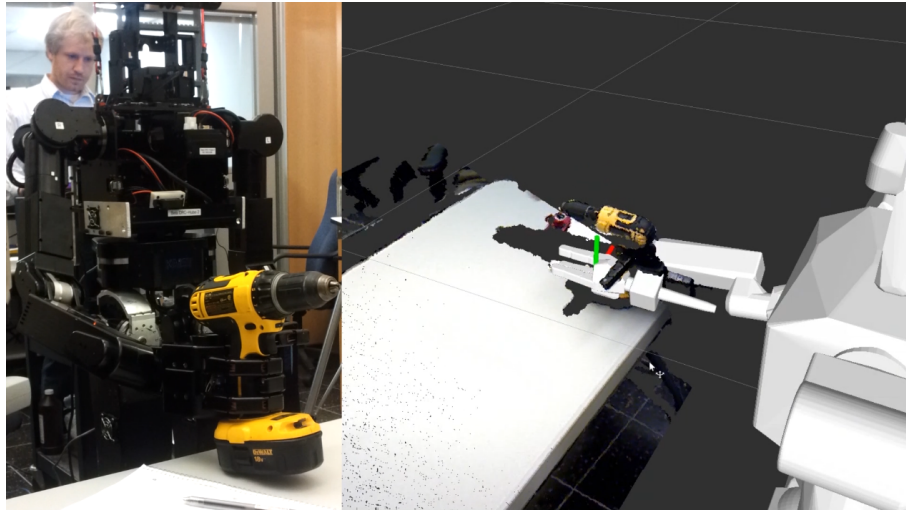


Figure 3: Picture of teleoperation of picking up a drill.

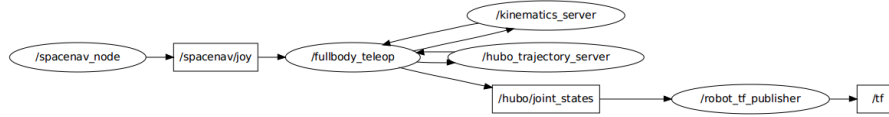


Figure 4: Simplified ROS Graph created by fullbody_teleop.launch.

Upcoming Features

This section lists the features which we intend to implement and stabilize prior to the DRC. Many of these features we consider to be crucial for successful teleoperation of the task.

1. End effector Force-Torque workspace control
2. Cooperative dual-arm manipulation
3. Simultaneous dual-arm manipulation
4. Human-assisted planning phase for collision avoidance

Troubleshooting

Table 1: Troubleshooting Table

Symptom	Causes	Solution
Can't ssh to HUBO's PC	<ol style="list-style-type: none"> 1. Not on correct network. 2. Hubo's PC is stuck in the Grub menu 	<ol style="list-style-type: none"> 1. Connect to the correct network. 2. Connect a monitor and keyboard to Hubo's PC and debug, or just a keyboard and press enter.
Can't connect to the robot in RViz panel	<ol style="list-style-type: none"> 1. Not on the correct network. 2. The daemons are not running on Hubo 	<ol style="list-style-type: none"> 1. Connect to the correct network. 2. Ensure daemons are running by typing <code>ps aux grep daemon</code> or restarting Hubo and running <code>sudo service hubo-motion start</code>.
Receiving ACH_OVERFLOW from rviz command. HuboInitPanel joint names don't showing up correctly.	Don't have matching or most up-to-date installs of hubo-ach, hubo-motion-rt, hubomz or possible another repo.	Make sure you are on the right branch in each repo and reinstall on both machines.
Robot homes only the upper or lower body, or neither.	CAN line got corrupted.	Shutdown and turn off the Hubo PC and turn it back on and try again.