

MANIPULATION IN ROS USING BAXTER

DR. JUAN ROJAS

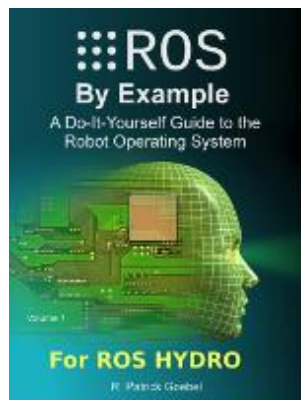
www.JuanRojas.net

Guangdong University of Technology
Biomimetics and Robotics Lab (BIRL)

ROS TRAINING DAY

June 16, 2016

ROS By Example



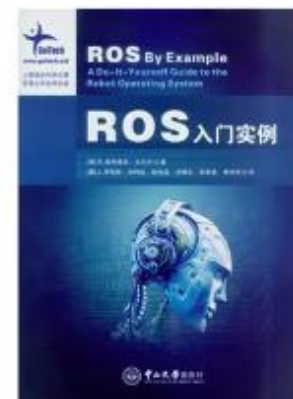
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- 由Peter Goebel著写的ROS实例系列书籍，在所有ROS文献中享有最多的版本数量。自从ROS发布了Electric版本以来，Patrick就开始为其编写该书籍，直到后来的Fuerte，Groovy，Hydro，Indigo和即将到来的Jade版本。随着ROS版本的更新，该书也不断更新。没有任何一本其他书籍拥有如此之多的修正，也没有任何一本其他书籍拥有如此大的奉献。
- ROS实例有两部书：这是目前市场上ROS类书籍中，唯一的一套涵盖内容如此全面的系列书籍。
- 本书拥有最好的源代码基础和源代码支持。《ROS入门实例》和《ROS进阶实例》都在github上分享高质量源代码。这些源代码被全世界的ROS爱好者广泛测试并改进，并且涵盖了从最简单的到相当高阶的ROS运行实例。
- 本书拥有最强的社区支持。数以百计的使用者在本书的谷歌论坛中活跃着。（<https://groups.google.com/forum/#!forum/ros-by-example>）
- 本书是在Juan Rojas博士的指导下，由拥有机器人专业知识的学生工作组翻译而成。Juan Rojas博士在机器人领域研究长达14年之久，是ROS专家，也是机器人工程师专业团队的一员。毫无疑问你将获得质量上乘的译本

ROS by Example Vol. 2 Indigo – coming out in the Fall of 2016!!

SUPPORT PROGRAMS

APT-GET

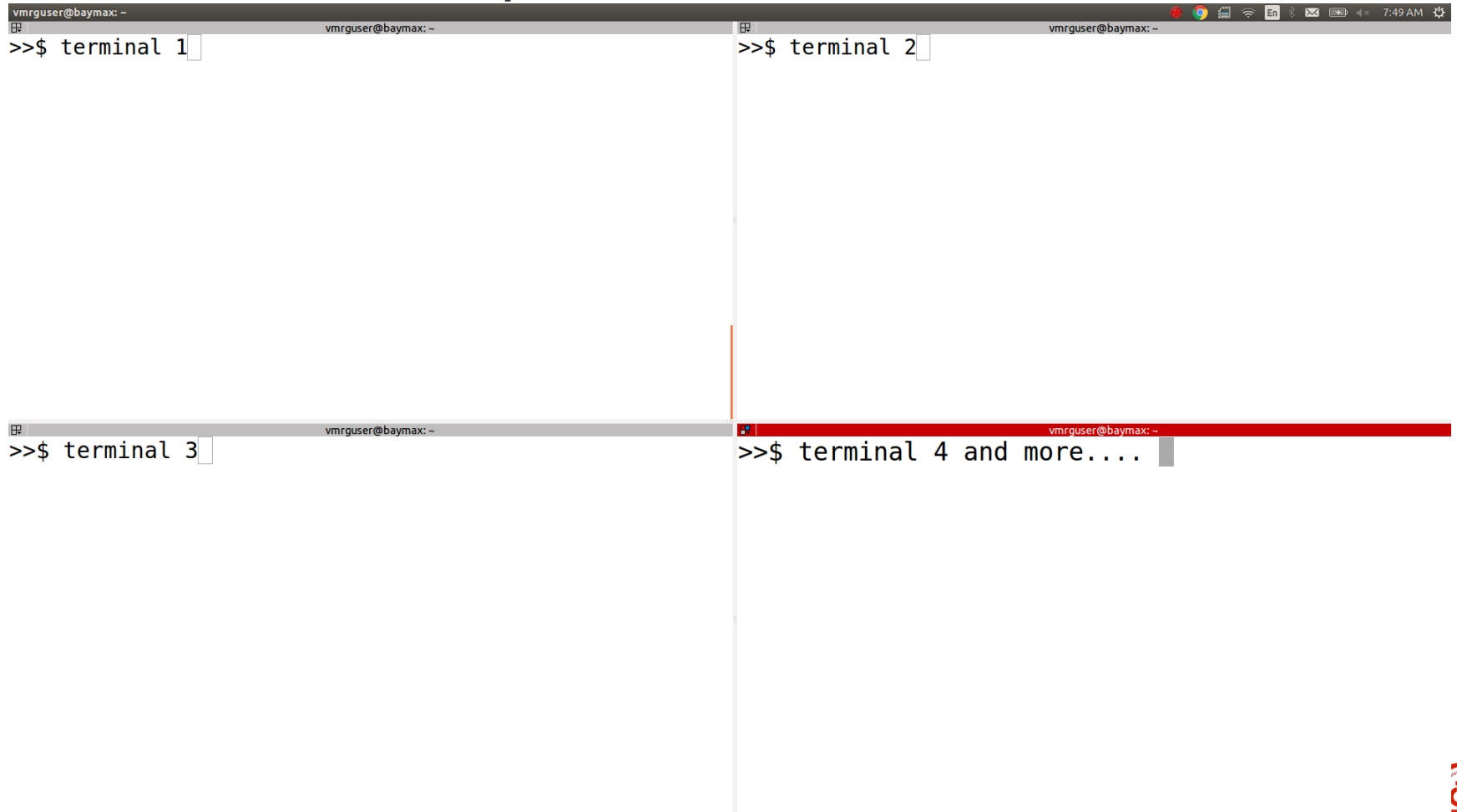
- Used to download programs in linux

```
sudo apt-get update
```

```
sudo apt-get upgrade
```

TERMINATOR

Great to run multiple terminals in the same window.



EMACS OR VIM

- Extremely powerful editor and more.
 - Powerful editor
 - Strong integration with GDB/PDB

Live terminals

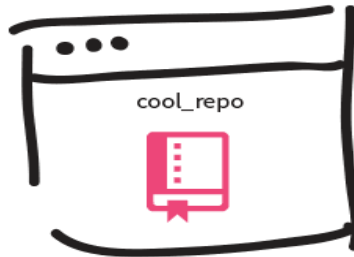
Easily expandable

```
emacs@baymax
File Edit Options Buffers Tools Gud Complete In/Out Signals Help
Set Breakpoint x p Continue Next Line Step Line Up Stack Down Stack i
1 #!/usr/bin/env python
2 import ipdb
3 import sys
4 import argparse
5 import rospy
6 from math import pi
7
8 import baxter_interface
9 from baxter_interface import CHECK_VERSION
10 from hand_action import GripperClient
11 from arm_action import (computerIK, computerApproachPose)
12
13 from pa_localization.msg import pa_location
14 from birl_recorded_motions import paHome_rightArm as rh
15 from copy import copy
16 import PyKDL
17 import tf
18
19 import threading
20
21 # Uses a thread class to block the subscription spin.
22 # Thread calls a subscriber pointing to topic pick_location, with msg type pa_location, a
    and callback self.callback.
23
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29
30 self._lock=threading.Lock()
31 self._thread=threading.Thread(target=self.picking_location_listener)
32 self._thread.start()
33
34 def picking_location_listener(self):
35     rospy.Subscriber("pick_location",pa_location,self.callback)
36     rospy.spin()
37
38 def callback(self,msg):
39     self.lock()
40     self._pose=msg
41     self.unlock()
42
43 def getPose(self):
44     return self._pose
45
46 def lock(self):
47     self._lock.acquire()
48
49 def unlock(self):
50     self._lock.release()
51
52 def main():
53     # Current directory is ~/ros/indigo/birl_baxter_ws/src/birl_demos/pick_n_place_demo/pa_demo/scripts/pa_demo/
54     > /home/vnrguser/ros/indigo/birl_baxter_ws/src/birl_demos/pick_n_place_demo/pa_demo/scripts
55     & /pa_demo/pa_manipulation.py(2)<module>()
56     -> import ipdb
57     (Pdb)
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GIT

REMOTE

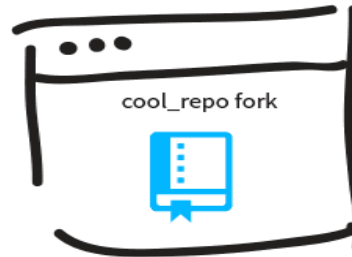
Someone else's repository.



Fork!

REMOTE

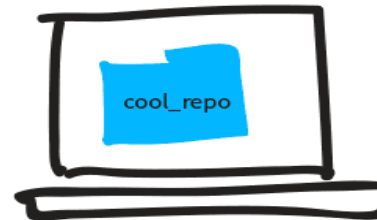
Your fork of the repository.



Push and Pull to your fork 'origin'.

Clone to your computer from GitHub.

Pull from 'upstream' changes to original.

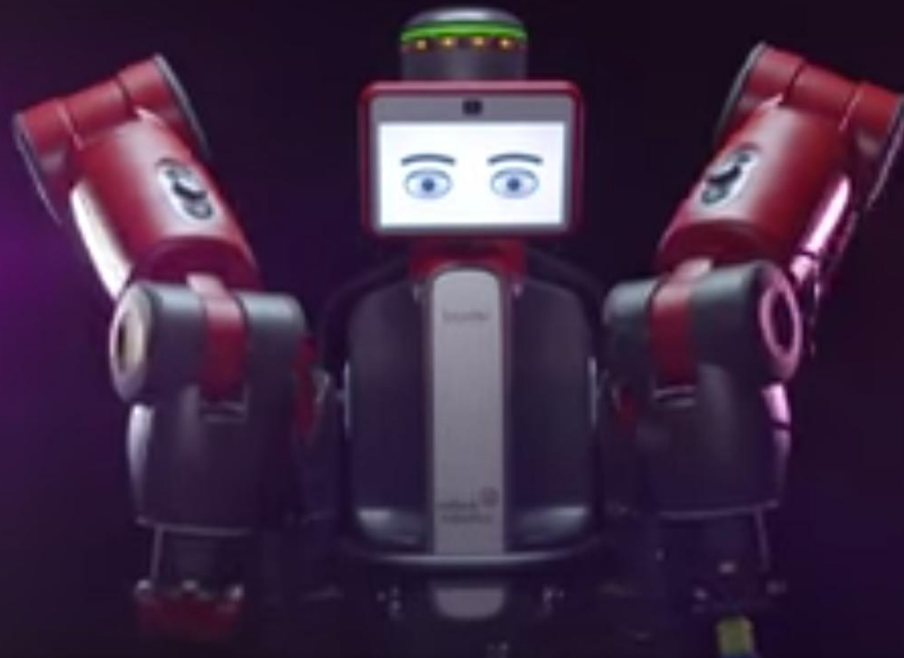


LOCAL

Use your computer's terminal to talk to two repositories via two remotes to the GitHub servers.

GETTING TO KNOW BAXTER

So, what can this robot do?



KITTING



PACKAGING



**LOADING &
UNLOADING**



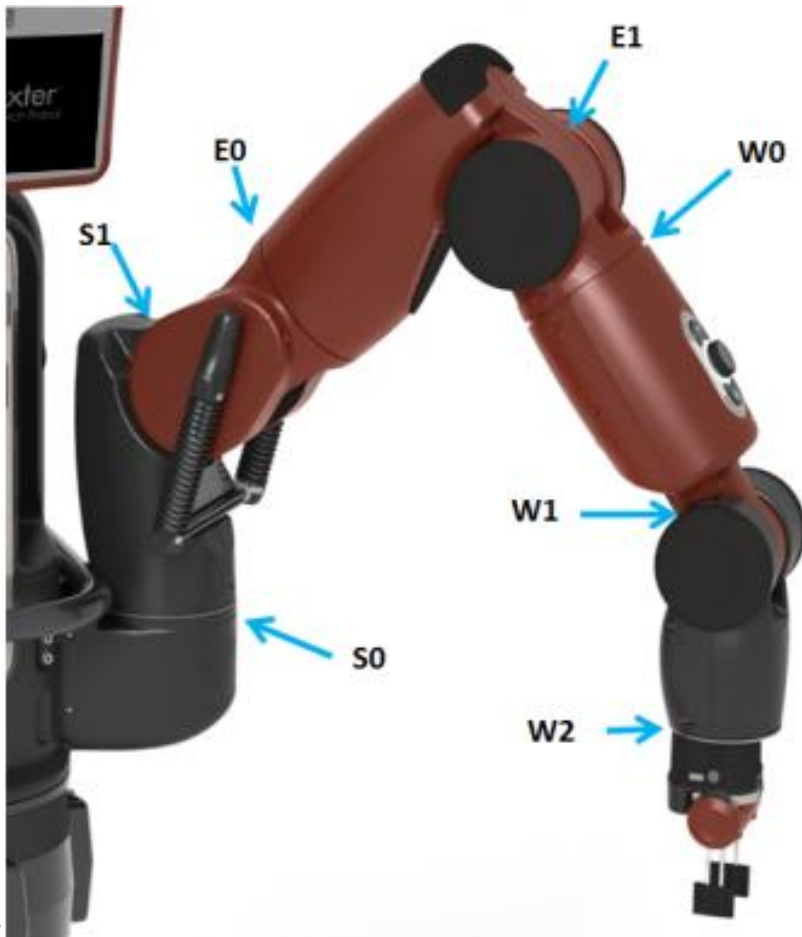
**MACHINE
TENDING**



**MATERIAL
HANDLING**

Baxter's Arms

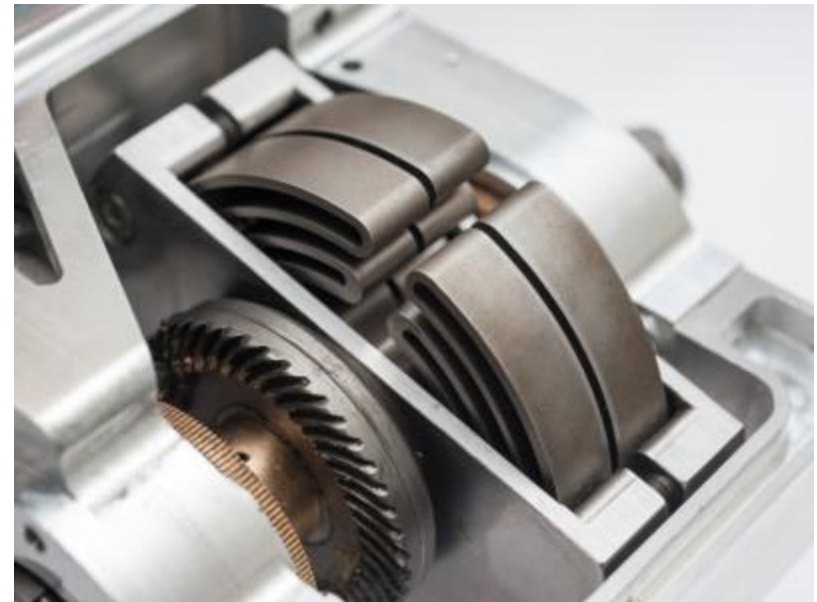
7 Degrees of Freedom (DoF)
7vs6 DoF = wider mobility.



Series Elastic Actuators

Spring between motor/gear:

1. Stable, low-noise Force Control.
2. Compliant.
3. Measure Torque at each joint.



Programming Layers

API

- Python interface for Baxter.
- Interface interacts with ROS.
- Goal to facilitate programming.

SDK

- Defines ROS: messages, topics, services, action libs.
- Also provides command line tools.

Getting the Baxter Code

- Open source @ sdk.rethinkrobotics.com/wiki/Workstation_Setup



Contents [\[hide\]](#)

Description
Required Hardware
Step 1: Install Ubuntu
Step 2: Install ROS
Step 3: Create Baxter Development Workspace
Step 4: Install Baxter SDK Dependencies
Step 5: Install Baxter Research Robot SDK
Step 6: Configure Baxter Communication/ROS Workspace
Step 7: Verify Environment
Video
Next Step
Trouble?

Baxter's SDK

- As part of the SDK, Rethink has defined:

- Topics: `/robot/limb/....`

- `/robot/head/...`

- Message Types:

- `baxter_core_msgs/`

- Parameters:

- `/baxter_emulator/left_gripper_type`

- Services:

- `/ExternalTools/PositionKinematicsNode/IKService`

- Action Libs:

- `/robot/limb/<limb>/follow_joint_trajectory/feedback`

- `/robot/limb/<limb>/follow_joint_trajectory/result`

- `/robot/limb/<limb>/follow_joint_trajectory/status`

- User Tools

- `roslaunch baxter_tools`

Getting Baxter Started

- Setting the Baxter environment:

```
>> roscd      (ROS_WORKSPACE=/your_fav_ws_path)
>> ./baxter.sh (sim for simulator)
```

- Starting the Simulator:

```
>> roslaunch baxter_gazebo baxter_world.launch
```

- For real Baxter, you can check for automatic connection:

```
>> roslaunch baxter_gazebo baxter_world.launch
```

```
[baxter - http://011405P0002.local:11311] >>$ rostopic list
```

Baxter's Arm and Head Joints

- The 7 DoF arms and Head pan consists of joints states, including:
 - Position – joint angles (radians)
 - Velocities – joint velocities (rad/s)
 - Effort – torque exerted at each joint (Nm)

•
Topic

```
/robot/joint_states
```

- Message Type:

```
sensor_msgs/JointState
```

Baxter's Arms: Control Modes

- Arms can be controlled in 4 different modes. Top 3:
 - **Position Control** – controller moves to target joint angles
 - **Velocity Control** – controller moves to target joint velocities
 - **Torque Control** – controller moves to target joint torques
- Switch modes by pub commands (pos,vel,effort) @ > 5Hz

```
/robot/limb/<side>/joint_command (baxter_core_msgs/JointCommand.msg)
```

- Message Type: baxter_core_msgs/JointCommand

```
int32 POSITION_MODE=1, int32 VELOCITY_MODE=2,  
int32 TORQUE_MODE=3, int32 RAW_POSITION_MODE=4  
int32 mode,  
float64[] command  
string[] names
```


Move Arm Manually...

```
rostopic pub -r 1000  
/robot/limb/right/joint_command  
baxter_core_msgs/JointCommand  
'{mode: 1, command: [0.1744], names: ['right_s0']}
```

Publish to joint_command

- Manually test right position/velocity control.
- Simple Position Control Command

```
rostopic pub -r 10 /robot/limb/right/joint_command  
baxter_core_msgs/JointCommand '{mode: 1,  
command: [-1.0], names: ['right_s0']}'
```

- Simple Velocity Control Command

```
rostopic pub -r 10 /robot/limb/right/joint_command  
baxter_core_msgs/JointCommand '{mode: 2,  
command: [-0.01], names: ['right_s0']}'
```

EndPointState

- Provides the following at the end-effector:
 - **Pose** (m)
(position, orientation)
 - **Twist** (m/s)
(lin vel, angular vel)
 - **Wrench** (N/m)
(forces, torques)

```
/robot/limb/<side>/endpoint_state (baxter_core_msgs-EndpointState)
```

BAXTER API

API

What is the API?

A new layer of code (based on python) is built on top of ROS.

- Instead of having to:
 - Publish or subscribe
 - Call services
- Call one of the API methods and
 - read/write data through function arguments.
- API is organized according to:
 - Modules
 - Sub-modules.

The Baxter Interface – Python Module

- `baxter_interface`
 - This module consists of sub-modules to help interact with different parts of the robot.
 - Each sub-module consists of a class of the same name.
`baxter_interface::limb::Limb`
 - The class is a wrapper around ROS communications.
- Sub-Modules (Interfaces)

Robot Enable	Limb	Head	Camera
Gripper	Navigator	Digital IO	Analog IO

Limb

- Limb is the *class* within the limb sub-module.
 - Queries the joint state
 - Switches between control modes
 - Sends Joint Commands (pos, vel, torque)

```
from baxter_interface import Limb
```

```
right_arm = Limb('right')  
left_arm = Limb('left')
```

- Topics

```
/robot/joint_states  
/robot/limb/<side>/joint_command
```

Limb Class Overview

- The methods below consider position only but...
- The same routines exist for **velocity** and **effort**.

[str]	<code>joint_names(self)</code> Return the names of the joints for the spec
float	<code>joint_angle(self, joint)</code> Return the requested joint angle.
dict({str:float})	<code>joint_angles(self)</code> Return all joint angles.

dict({str: Limb.Point ,str: Limb.Quaternion })	<code>endpoint_pose(self)</code> Return Cartesian endpoint pose {position, orientation}.
--	---

	<code>set_joint_positions(self, positions, raw=False)</code> Commands the joints of this limb to the specified positions.
--	--

	<code>move_to_neutral(self, timeout=15.0)</code> Command the joints to the center of their joint ranges
--	--

BAXTER REPO

<https://github.com/birlrobotics/>

Create ROS Workspace

```
$ mkdir -p ~/ros_ws/src  
# ros_ws (short for ROS Workspace)
```

Source ROS Setup

```
$ source /opt/ros/indigo/setup.bash
```

Build and Install

```
$ cd ~/ros_ws  
$ catkin_make  
$ catkin_make install
```

Install SDK Dependencies

```
$ sudo apt-get update  
$ sudo apt-get install git-core python-argparse python-wstool python-vcstools python-rosdep ros-indigo-control-msgs ros-indigo-joystick-drivers
```

Install Baxter SDK

Using the [wstool](#) workspace tool, we will checkout all required [Baxter Github Repositories](#) into your ROS workspace source directory.

```
$ cd ~/ros_ws/src  
$ wstool init .  
$ wstool merge https://raw.githubusercontent.com/RethinkRobotics/baxter/master/baxter_sdk.rosinstall  
$ wstool update
```

Build and Install

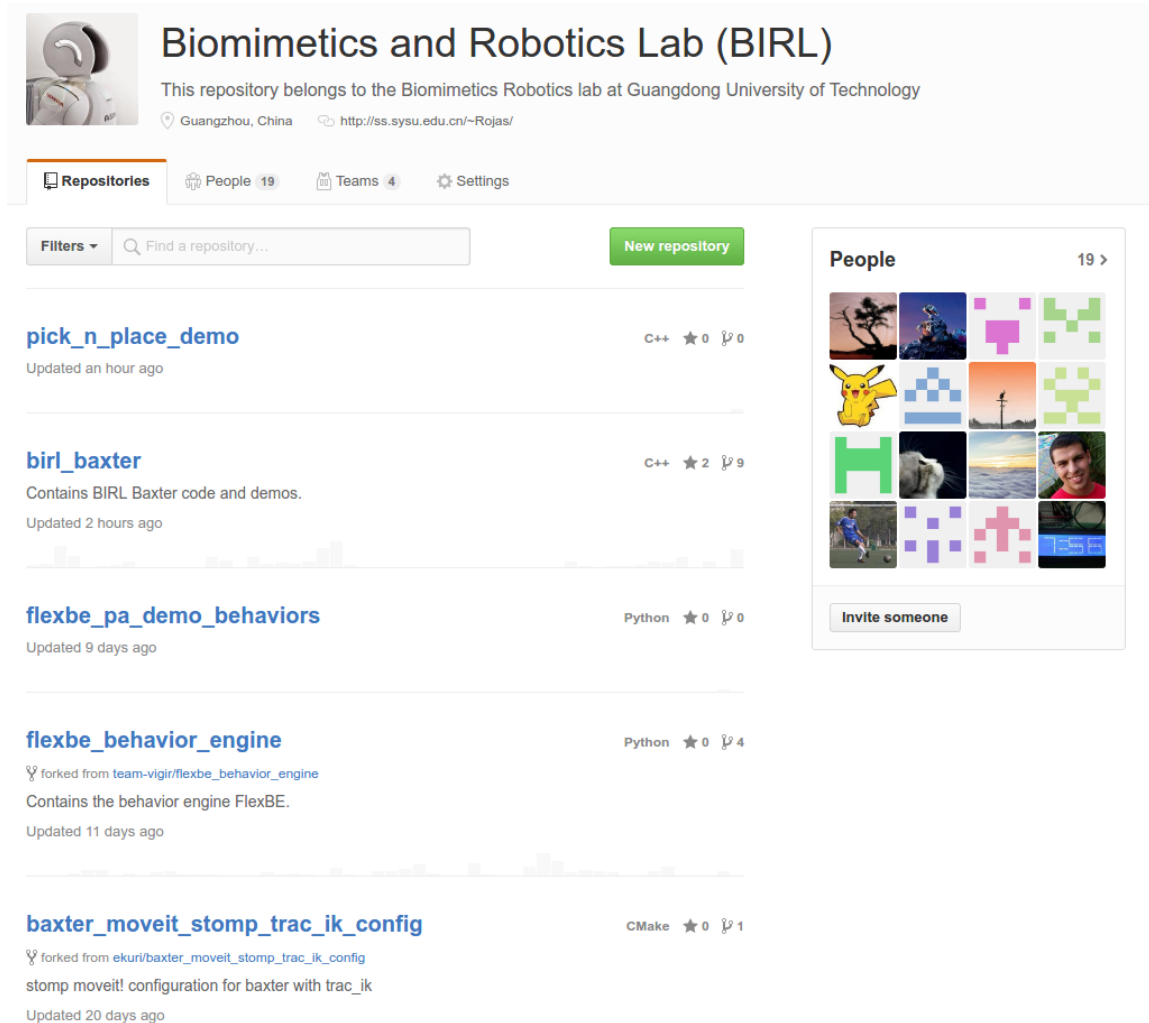
```
$ cd ~/ros_ws  
$ catkin_make  
$ catkin_make install
```

BIRLROBOTICS REPO

<https://github.com/birlrobotics/>

BIRL Robotics GitHub Repo

<https://github.com/birlrobotics>



Biomimetics and Robotics Lab (BIRL)
This repository belongs to the Biomimetics Robotics lab at Guangdong University of Technology
Guangzhou, China <http://ss.sysu.edu.cn/~Rojas/>

Repositories | People 19 | Teams 4 | Settings

Filters | Find a repository... | New repository

- pick_n_place_demo** C++ ★ 0 🍴 0
Updated an hour ago
- birl_baxter** C++ ★ 2 🍴 9
Contains BIRL Baxter code and demos.
Updated 2 hours ago
- flexbe_pa_demo_behaviors** Python ★ 0 🍴 0
Updated 9 days ago
- flexbe_behavior_engine** Python ★ 0 🍴 4
forked from [team-vigir/flexbe_behavior_engine](#)
Contains the behavior engine FlexBE.
Updated 11 days ago
- baxter_moveit_stomp_trac_ik_config** CMake ★ 0 🍴 1
forked from [ekuri/baxter_moveit_stomp_trac_ik_config](#)
stomp moveit! configuration for baxter with trac_ik
Updated 20 days ago

People 19 >

Invite someone

BAXTER EXAMPLES

Baxter Examples

<http://sdk.rethinkrobotics.com/wiki/Examples>

SDK Examples

Fundamentals

[Enable Robot Example \(Start Here\)](#) - This tool is responsible for enabling (powering and state monitoring) Baxter. Enabling the robot

Movement

[Joint Position Waypoints Example](#) - The basic example for joint position moves. Hand-over-hand teach and recording a number of

[Joint Position Keyboard Example](#) - This example demonstrates numerous joint position control.

[Joint Position Example](#) - Joystick, keyboard and file record/playback examples using joint position control of Baxter's arms.

[Joint Torque Springs Example](#) - Joint torque control example applying virtual spring torques.

[Joint Velocity Wobbler Example](#) - Simple demo that moves the arm with sinusoidal joint velocities.

[Joint Velocity Puppet Example](#) - Simple demo which mirrors moves of one arm on the other in Zero-G.

[Inverse Kinematics Service Example](#) - Basic use of Inverse Kinematics solver service.

[Simple Joint Trajectory Example](#) - Simple demo using the joint trajectory interface.

[Joint Trajectory Playback Example](#) - Trajectory playback using the joint trajectory interface.

[Head Movement Example](#) - Simple demo moving and nodding the head.

[Head Action Client Example](#) - A demo to showcase the functionality of the head trajectory action server.

[Gripper Example](#) - Joystick and Keyboard control for the grippers.

[Gripper Cuff Control Example](#) - Simple cuff-interaction control with Zero-G mode.

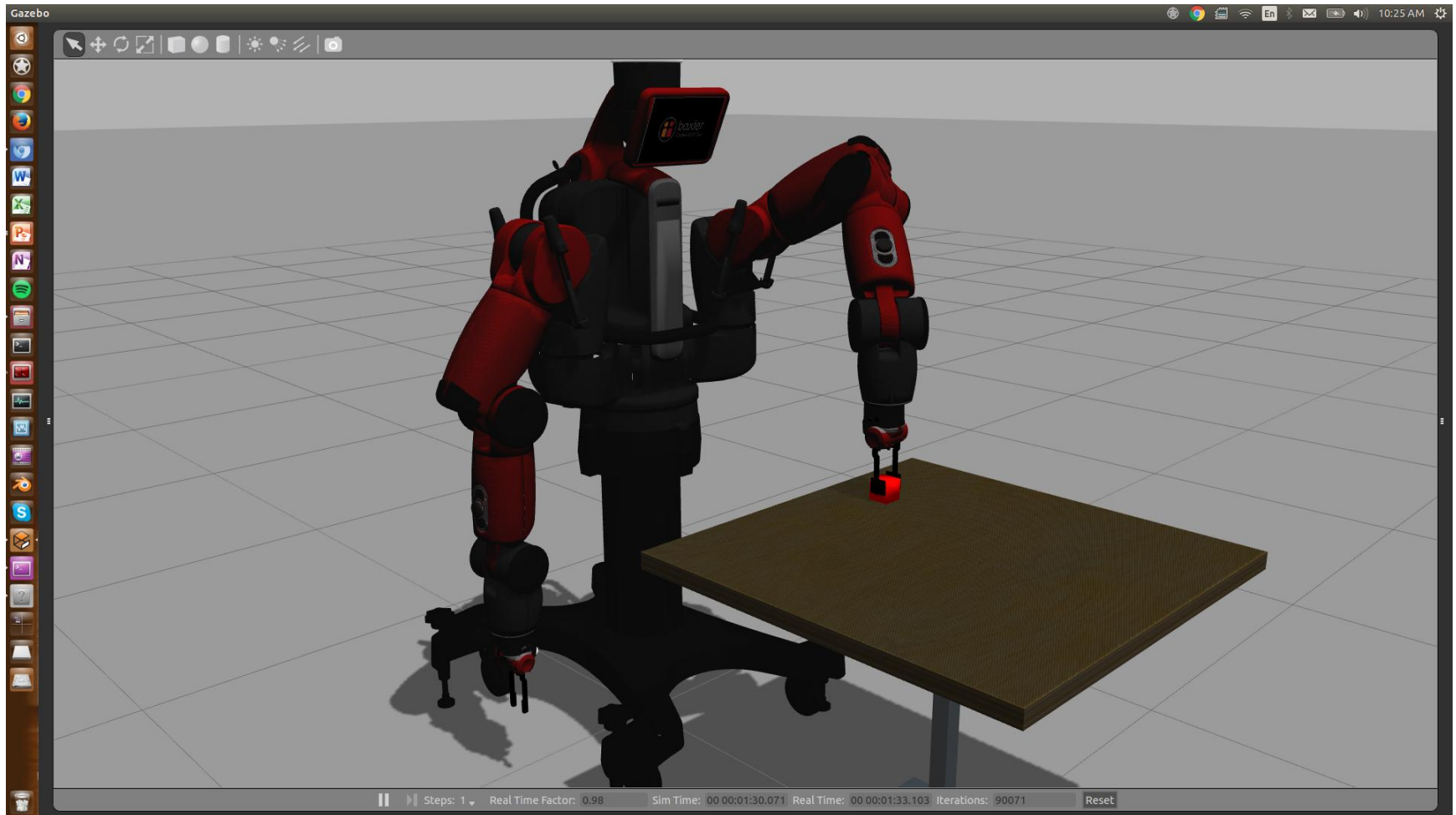
Robot Configuration

[URDF Configuration Example](#) - A simple ROS node that shows how to add segment and joint subtrees to the robot's model.

Simulator

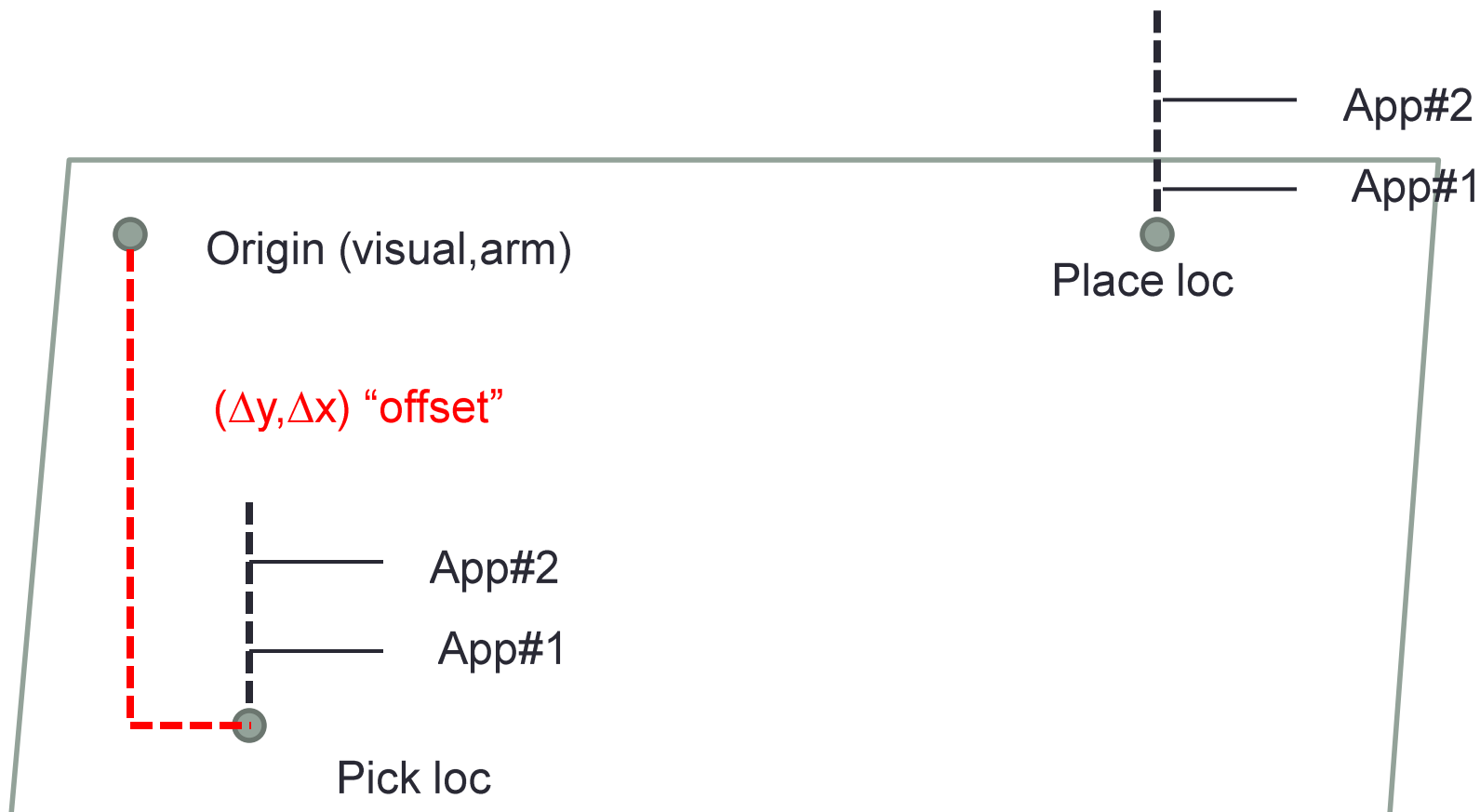
[IK Pick and Place Demo](#) - An intermediate example for combining Inverse Kinematics Service calls with Arm movement, gripper at

Baxter_Sim_Examples



THE MANIPULATION TASK

Experiment Set-Up



VISUAL LOCALIZATION

CALIBRATION

Visual Calibration

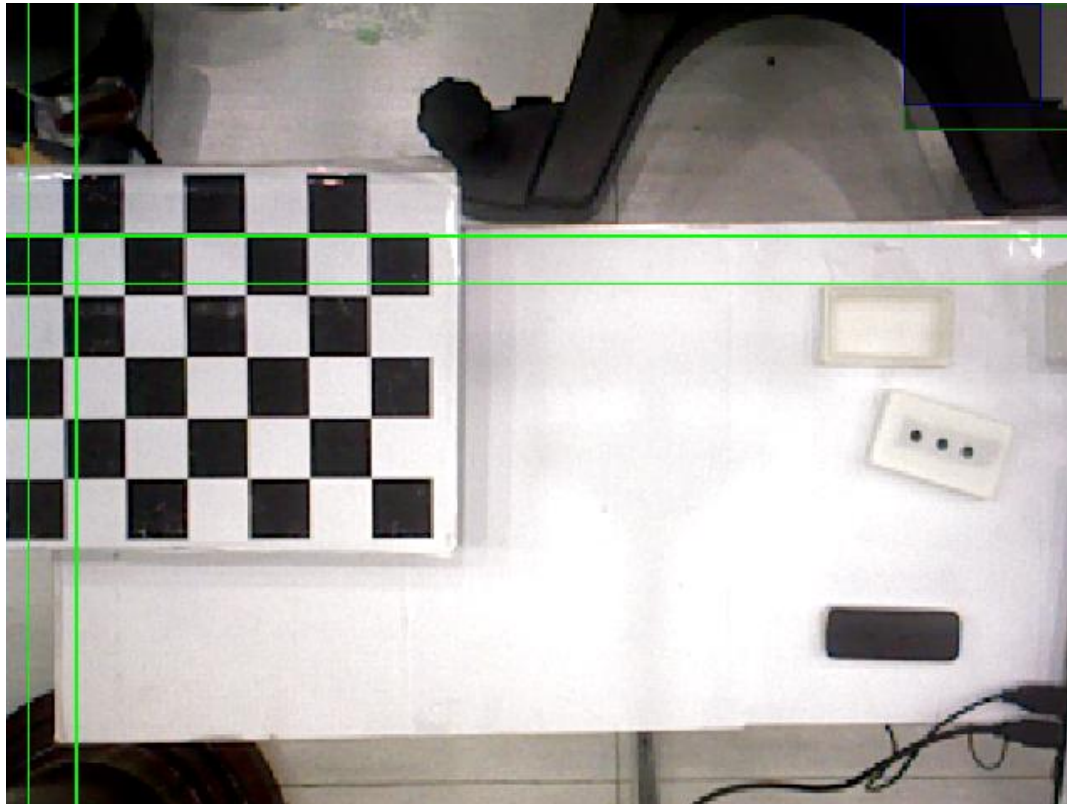
- All cameras need to be calibrated.
- Two main types of calibration:
 - Intrinsic Calibration: defines internal parameters of the camera
 - Extrinsic Calibration: defines transforms between cameras/camera-robot
- Packages
 - Openni Calib:
http://wiki.ros.org/openni_launch/Tutorials/IntrinsicCalibration
http://wiki.ros.org/openni_launch/Tutorials/ExtrinsicCalibration
 - ROS Camera Calib
http://wiki.ros.org/camera_calibration

Visual Calibration: Origin

- Run the calibration algorithm

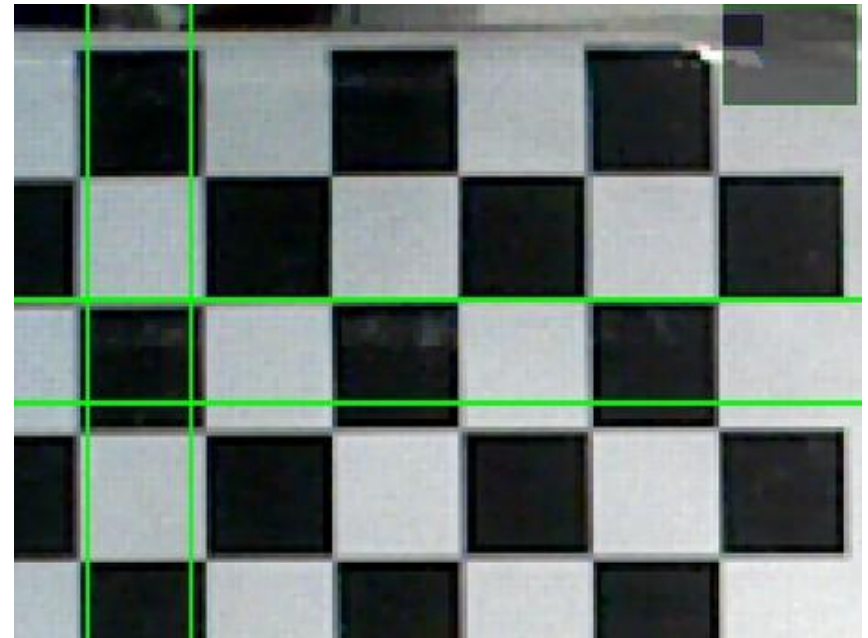
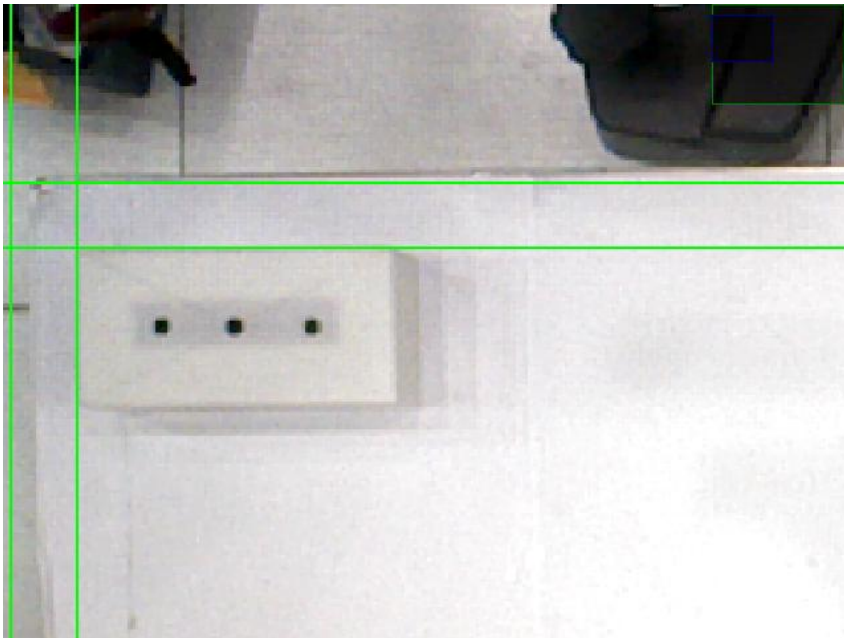
```
roslaunch oppeni2_launch oppeni2.launch  
rosrun pa_localiztion table_pos_calibration.py
```

- Define the origin as the crossing of two green lines

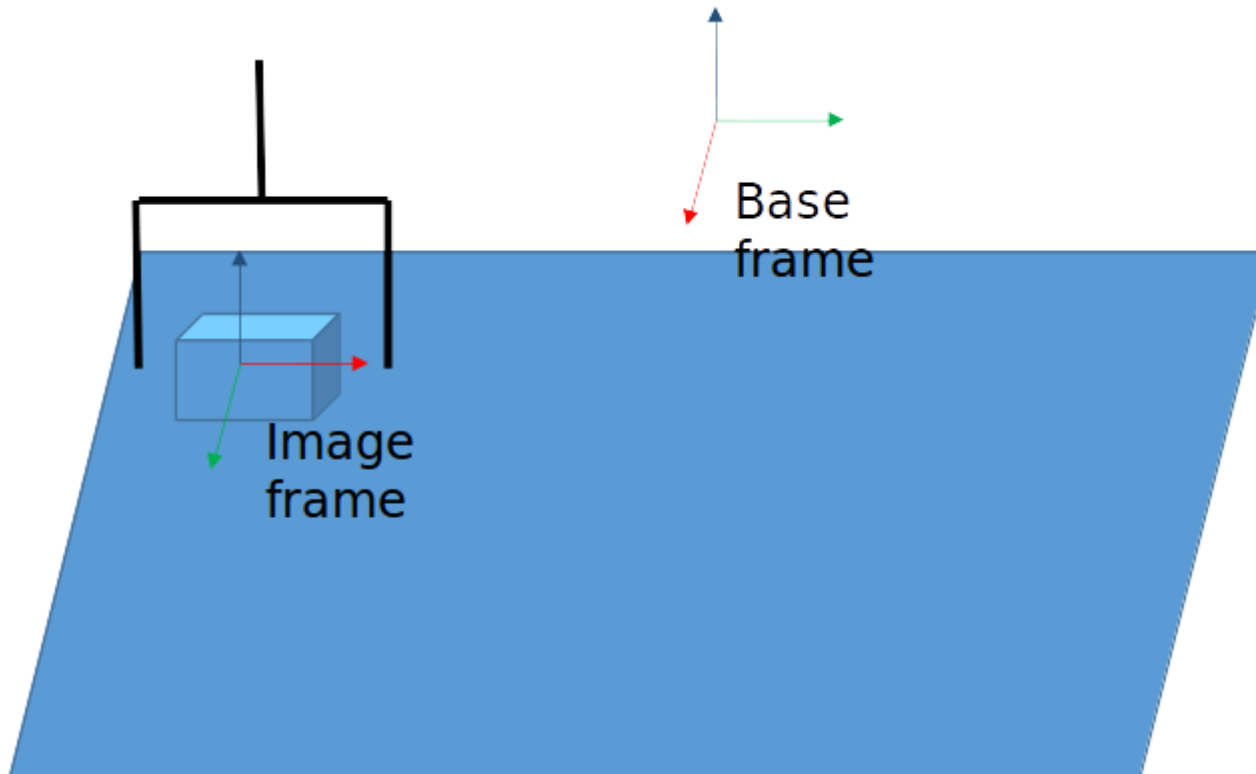


Visual Calibration: Pixel Scale for Objects

- Place object corner on origin.
- Place checkerboard on top.
- With a ruler measure distance of block.
- Then with opencv image viewer count the number of pixels across 1/2/3 blocks and compute average



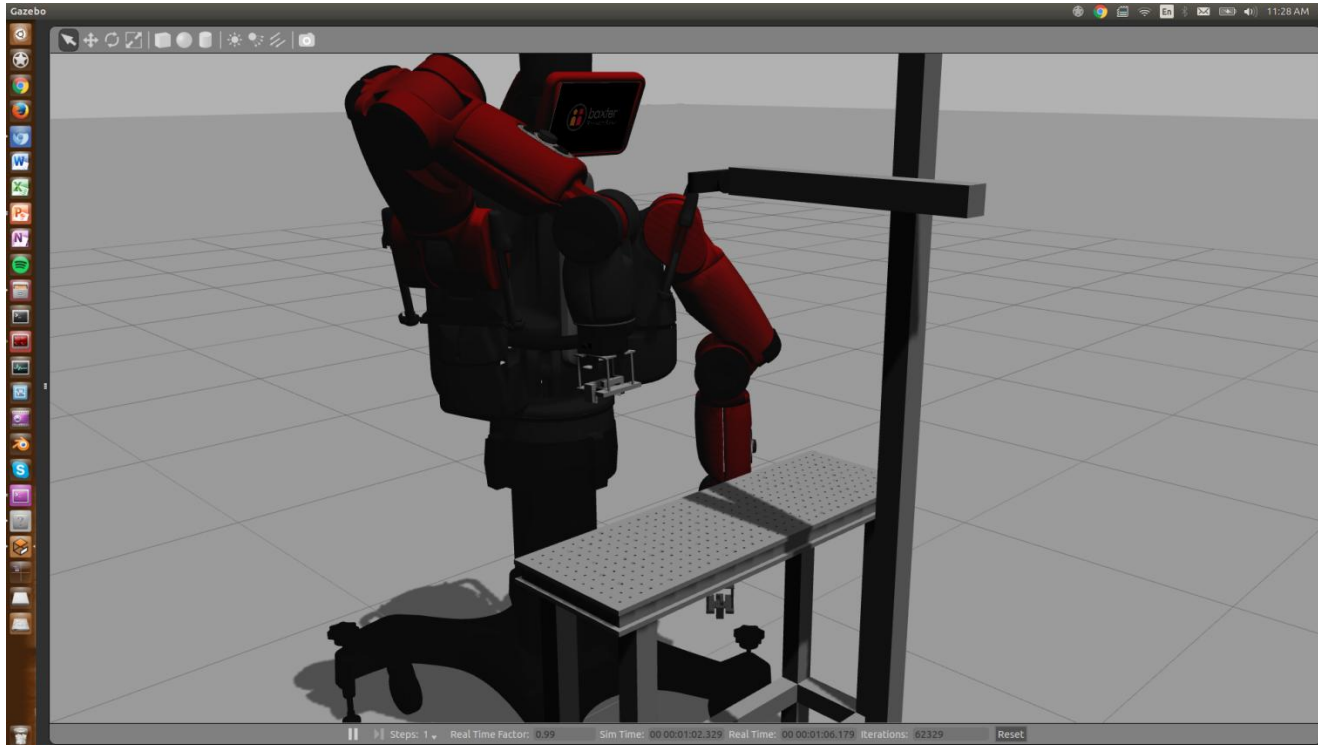
- Place object @ origin of image frame
- Teleoperate robot arm to grasp object
 - Record current end point position as reference point.



MANIPULATION

Live Demonstration

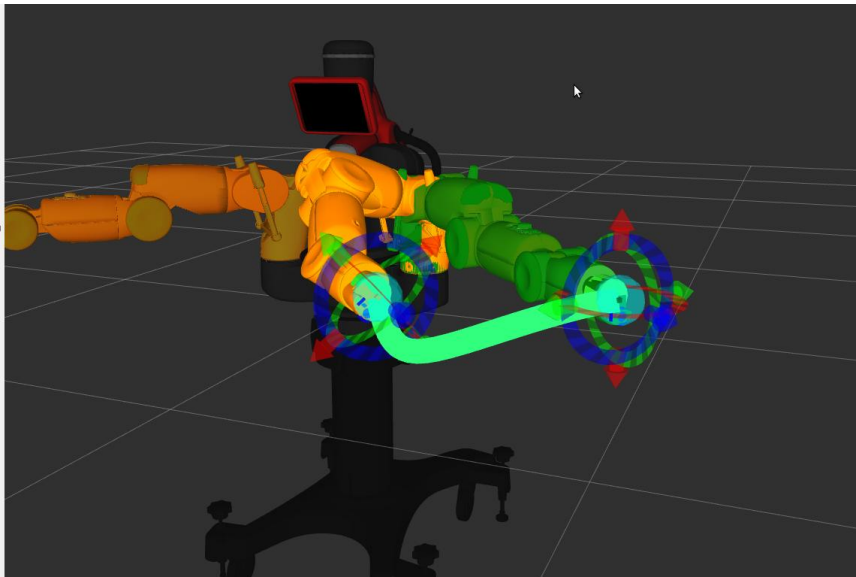
- Follow the code @ this [link](#)
- We will step through it, using ipdb.



OTHER POSSIBILITIES

Different Ways of Moving

- Instead of moving point-to-point...
 - Use the trajectory_action_server
 - Helps you keep track of trajectory
 - Use motion_planning: try our [stomp](#)-track [here](#).



Different Kinematic Solvers

- This one is using Baxter PyKDL
 - Based on Orocos KDL

- Other Solutions

- IK_Fast from openrave
- Track_IK

https://github.com/birlrobotics/birl_baxter/tree/master/birl_manipulation/birl_kinematics

QUESTIONS
