Hands-on 6: Adapting the manipulation stack to in-hand manipulation

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Outline

1. Object manipulation stack overview
2. Integration on your robot
3. Towards in-hand manipulation
4. Integrated example
5. Conclusion

1 Object manipulation stack overview

- Introduction
- Stack Description
- Structure
- Previous session recap

Context

- ROS Electric on Ubuntu Lucid, Natty and Debian Squeeze
- Presentation of the stack from User point of view
- Future version called Move It ! not treated here
- Based on HANDLE project development experience
- Providing feedback on common or specific issues

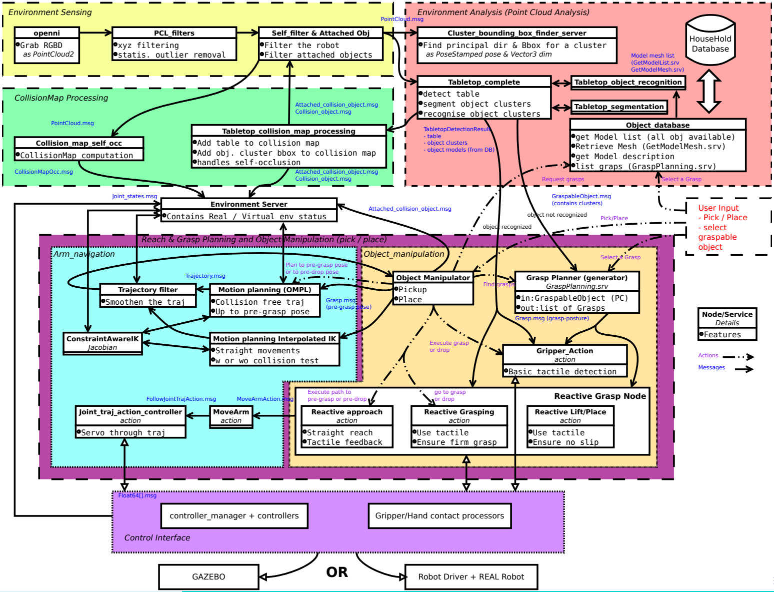
What is it ?

Current version of packages for object manipulation with any robot manipulators to perform object pickup and placing.

- Main Stack
  - **Household_objects_database** : mesh & grasps
  - **Object_manipulator** : core application
  - **Probabilistic_grasp_planner** : grasp generator
- Major Dependencies
  - **Arm_navigation** : dealing with arm movements
  - **Motion_planning** : access to planning libraries
  - **Kinematics** : computing robot kinematics
  - **Sql_database** : access to database

Manipulation Diagram

http://www.ros.org/wiki/object_manipulator#Grasping_and_Placing:_Details_and_Implementation Diagram by Guillaume WALCK - www.handle-project.eu



Subsets

- Environment sensing (vision in Hands-on 1 & sensing in Hands-on 4)
- Environment analysis (transforms in Hands-on 2)
- CollisionMap processing (in Talk 3)
- Arm navigation (in Talk 3)
- Object manipulation (in Talk 3)
- Drivers (in Hands-on 3)

Hands-on 1 Visual perception system

- Kinect: understanding and ROS integration
- System for robotic visual perception
  - Calibrating a Kinect with respect to the robot
  - Reconstruction
  - Object recognition: known objects stored in a database
  - Pose estimation of the object
- Interfacing with an object SQL database

Hands-on 2 Managing coordinate frames

- Reference Frames: Visualizing the tree
- Creating static transforms
- Transform broadcast → publishing transforms
- Robot urdf model
- Transform listener → LookupTransform
- Transform Point/Vector/Pose
- Transforms and time-keeping → Application in object tracking

Hands-on 3 Control of the Shadow dexterous hand

- Ethercat motor hand
- 1KHz realtime loop updates:
- Hand HW drivers
- Controllers
- User interaction with controllers using command topic

2 Integration on your robot

- Pre-requirements
- Wizard

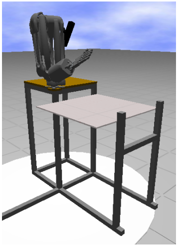
Overview

- URDF : handling several robots
- TF: linking robots and timing issues
- Control: robotstate and controllers
- Sensing: tactile & vision
- Database: objects & grasps

URDF: handling several robots

- Robot description
  - Required by many nodes: TF , IK, planning, visualization
  - Keep it modular: robot separated from platform
  - Dealing with 2 linked robots: hand & arm
  - Simplify collision models
- Simulation world
  - Platform: model attached to world link
  - Objects: realistic but should remain lightweight models
  - Scenarios: launch files spawning several objects

Ladle model



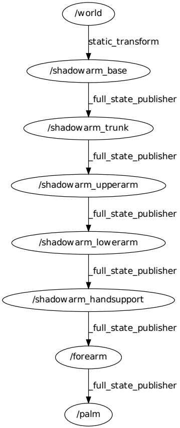
Platform

TF: linking robots

Problem: 2 robots creating a complete manipulator

- Single robot
  - 1 complete joint_states from end-to-end
  - 1 state-publisher with a full URDF
- Multiple robots
  - 1 joint_states / state-publisher per robot
  - 1 joint_states merger (full js needed)
  - 1 static_transform to link the robots together
  - Full URDF still loaded as robot_description

⟹ Coherent TF linking equivalent to full URDF
⟹ Check for no duplicate TF state-publishing



TF: timing issues

- Context
  - 4 computers (hand, arm, vision, manip)
  - TF published by 3 of 4 computers (arm, hand, vision)
  - TF used by all the computers
- Requirements
  - Coherent URDF / State Publishers (non overlapping)
  - Synchronization of time

$\Longrightarrow$ NTP deamon is **MANDATORY**

Control: robotstate (1)

Robotstate with 2 robots on 2 different buses linked together ?

- YES: robots based on torque commands
  - Ethercat drivers & non-ethercat drivers in realtime loop
  - One **pr2_controller_manager** handles all the controllers
  - Robotstate containing joints/actuators from end-to-end
  - All controllers in **robot_mechanism_controllers** can work
- NO: robots based on mixed type commands
  - Robotstate is only dealing with torque demands
  - No controller in **robot_mechanism_controllers** can work

Control: robotstate (2)

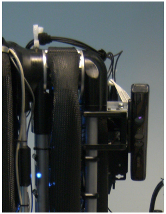
- Solution: use velocity/position commands
  - Drivers fill own robotstate in separate realtime loops
  - Multiple CM + service (listcontrollers , ...) dispatching node
  - No generic robotstate $\Longrightarrow$ create a getJointState service
  - Custom designed controllers (ex: muscle pressure commands)

Control: controllers

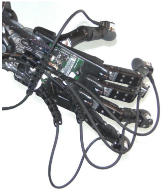
- Types required by **move_arm** execution
  - Joint trajectory action controller
  - Cartesian space controller
- High-level control loop for non-torque controlled multi-robots
  - Manages the joint_trajectory or cartesian controllers
  - Connects velocity/position commands output to low-level controllers input topics
  - Running at 100-500Hz

Sensing: vision & tactile

- Vision device
  - Pointcloud acquisition
  - Calibration mean
  - Self-filtering
- Tactile device
  - Force and contact measuring
  - Gripper/hand grasp quality
  - Reactive actions



Kinect



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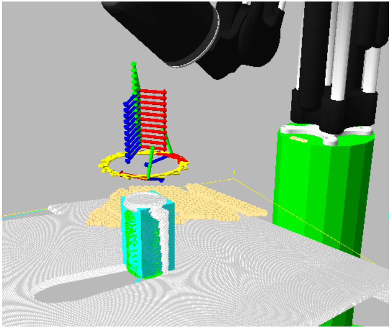
Database: objects & grasps

- Objects
  - Properties
  - Mesh model
- Grasps
  - Related to objects
  - Pre-grasp posture
  - Grasp pose
  - Grasp posture + quality



Grasp poses

- Object with symmetries with non-360 end-effectors
  - Bad object frame setup after recognition
  - Planning does not consider symmetry

$\Longrightarrow$ Generate poses around symmetry axis on-the-fly

Hints

- Setting-up
  - Add all the possible chains even if you don't use them
  - Adapt URDF files pointers (in case you use on-the-fly URDF generation from xacro)
  - Edit constraint_aware_kinematics.launch to add your own IK services (must be plugins)
- Testing
  - Launch the create_launch_files.py from **move_arm_warehouse**
  - Try the result in the generated warehouse_viewer application

3 Towards in-hand manipulation

- Comparison
- Adapting nodes
- Creating nodes

Similarities

- Pick & Place
  - Is an in-hand manipulation requirement
  - Approach/lift phases similar
- Planning
  - Fingers are mini serial manipulators
  - Object is added as an obstacle for the fingers
- High-level control
  - Joint trajectory controller works on fingers

Differences

- Object on table vs in hand
  - Tracking in-hand
  - Planning very close to objects
- Context only vs task & context oriented grasps
  - Task pre-conditions final grasp
  - Context pre-conditions initial grasp
  - In-hand transition planning
- Gripper vs fingers grasps
  - N-fingers
  - Grasp synergies
  - Force closure
  - Contact & slip detection

To cope with the similarities and differences:

- Existing nodes need to be adapted
- New nodes must be created

IK

- Manipulator: arm + wrist
  - Multi-robot but single URDF
  - **Arm_kinematics_constraint_aware package**
  - 6D IK generated automatically by **KDL**
- Hand: 5 fingers (<6 DoF)
  - Modify generic **arm_kinematics** node to solve 3D IK
  - Adapt **KDL** library to support coupling
  - **Kinematics_base** to derive a plugin usable in **OMPL**

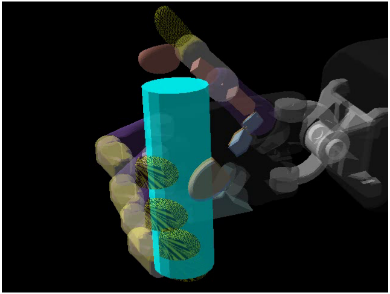
Grasps

- Access & description
  - Access node **household_objects_database** totally re-used
  - Grasp format configured through **hand_description** parameter
    $\Longrightarrow$ Never use "hand_description" word for an URDF describing a hand !
- Structure
  - Double precision vector in radians for joint angles
  - Pose given with translation and quaternions
    $\Longrightarrow$ quaternion values are (**qw**,qx,qy,qz) in DB but (qx,qy,qz,**qw**) in ROS message
- Execution
  - Basic interpolation between pre-grasp posture and grasp-posture
  - Rewritting **gripper_action** into **hand_posture_execution**

Finger movement planning

- Finger gaiting
  - To reconfigure the grasp
  - To avoid object parts with in-hand movements

    $\Longrightarrow$ Re-use **OMPL** node with custom IK
- Example: Moving the thumb in a power grasp
  - Plan the thumb movement to avoid object collision
  - Small padding needed



IK

- **KDL** creates iterative slow solutions

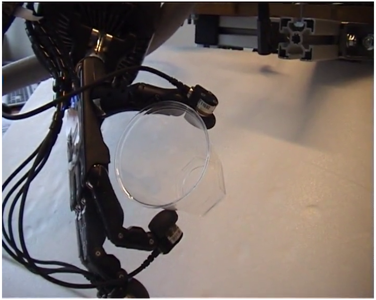
  $\Longrightarrow$Analytic solution is better for faster planning

- Openrave IKFast
  - Convert robot description from URDF to DAE
  - Generate cpp code
  - Integrate the code in a **kinematic_base** inherited plugin

Reactive Grasping

- Replaced by synergy grasping
  - Works on known & unknown objects
  - Stops each finger independently at contact
- Indirectly ensure force-closure
  - Impedance control on each fingertip in contact
  - Self-adjusts to stable grasp

Synergies for a tripod grasp



Impedance force control

In-hand planning

- Core application of the project
  - Learning transitions and grasps from Humans
  - Planning grasp transitions and action steps
  - Benefit from fingers dexterity
  - Synergy and geometric movement planners
- Integration
  - Services mostly triggered by manipulation stack messages
  - Using actionlib to easily cancel actions (object slippage)

Pick, Manipulate & Place

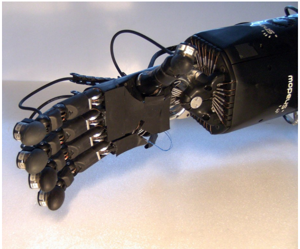
- Initial node
  - **Object_manipulator_node** is very complex
  - Too many cases hardcoded
  - Over protection difficult to remove
- Rewritting
  - Python application
  - Separate planning from execution
  - Redo basic pick and place
  - Add intermediate steps (grasp transitions)
  - Do something useful (action)

4 Integrated example

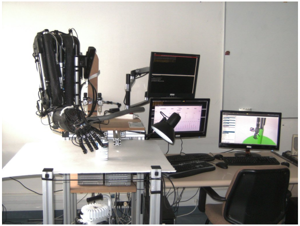
- Manipulation
- In-hand manipulation

Context

- HANDLE Platform
  - Shadow biomorphic arm
  - Shadow EDC motor hand
  - Kinect
  - ATI Nano17 F/T sensors
- Processing power
  - Far from PR2 power
  - 2 PC for robot/sensor drivers
  - 1 PC for image processing
  - 1 PC for manipulation stack



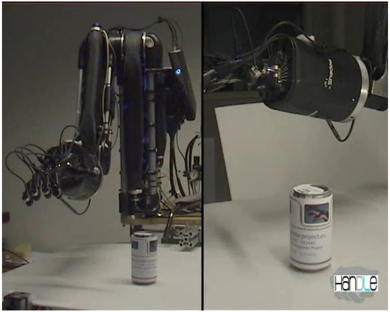
Hand



Platform

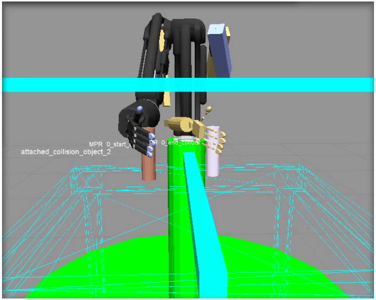
Pick

- Detect the can
- Extract a grasp, generate a symmetry
- Plan the approach with OMPL
- Perform the reactive grasp (interpolation)
- Lift (Place not working yet)

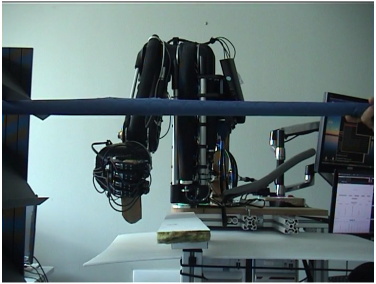


Object handling (1)

Warehouse_viewer with object attached to the hand



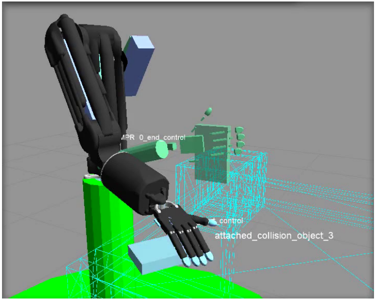
Insert a book in a slot (SIM)

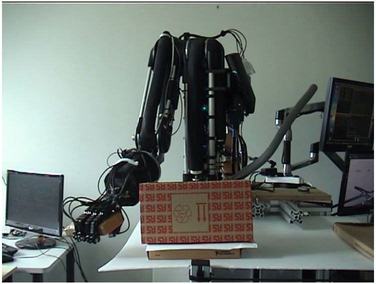


Insert a book in a slot (REAL)

Object handling (2)

Warehouse_viewer with object attached to the hand

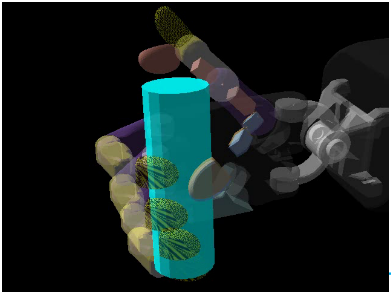




Insert a book in a slot (SIM) Insert a book in a slot (REAL)

Finger motion planning

Warehouse_viewer with object as obstacle



Thumb gaiting

Summary of tips & tricks

- Whenever possible, use existing messages/services
- Describe your robot (URDF , robotstate ,controllers,IK)
- Use provided wizards and re-use generic nodes (**KDL** , **OMPL**)
- Fill up the database for your application/hand
- Whenever possible store data in existing tables
- Complete the pipeline with missing nodes for your application

Manipulation stack

- Pros
  - Complete pipeline
  - Quite configurable (wizards)
  - Various useful standalone external apps
  - Very re-usable
- Cons
  - Complex, not documented enough
  - Still PR2 oriented, not generic enough

ROS

- Our developments always behind due to high pace of the main packages
- Complete with a lot of solutions ported to ROS
- Great sharing community

$\Longrightarrow$ definitely **time saver**

Questions ?

Any questions ?