UNIVERSITÀ DI PISA

ISTITUTO ITALIANO DI TECNOLOGIA

A Soft Robotics approach to Autonomous Warehouse Picking

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Introduction

- Automation of operations is one of the core aspects in industrialization.
- Robots can move heavy loads and perform relentlessly the same operation thousands times.
- Operators do not interact directly with the machines

The problem

- Several tasks still elude completely robotization
- Manipulation and object handling are among the most critical tasks where the human intervention is still irreplaceable
  - Heterogeneous object dimensions and shapes
  - High complexity when working in constraint environments
  - Perception issues

Amazon Picking Challenge

amazon Picking Challenge
ICRA 2015, Seattle WA

Amazon Inc. promoted a challenge to tackle Pick and Place task.

- Robot has to be completely automated
- Pick and Place task has to be executed on the standard Amazon workspace build for humans been
- Environment constrained

Amazon Picking Challenge

Operations of the challenge

- Extraction from a file of a list of items to collect
- Identification of the objects to be collected
- Picking up of the objects
- Placement of the objects in a box

Robot requirements

- Large outside workspace
  - Height 1700 [mm]
  - Width 1500 [mm]
  - Depth 1200 [mm]
- Small internal workspace
  - Height 260 ÷ 310 [mm]
  - Weight 318 ÷ 354 [mm]
  - Depth 800 [mm]
- Fully autonomous operation

Thesis Overview

- A novel strategy: environmental constraints exploitation
- Design of the robot
- Motion Planning algorithm
- Experiments

Problem Solution:

Environmental Constraint (EC) exploitation

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Environmental Constraint (EC) exploitation

- Features of the environment that enable replacing explicit control with interaction between hand, object and environment
- Elimination of the existing sharp separation between:
  - Perception
  - Planning
  - Control

Soft Robotics

- Novel technologies are been developed to solve the problem
  - Soft Actuators that can modulate their compliance
  - Passive adaptation of mechanical manipulator

Robot requirements

- Large outside workspace
  - Height 1700 [mm]
  - Width 1500 [mm]
  - Depth 1200 [mm]
- Small internal workspace
  - Height 260 ÷ 310 [mm]
  - Weight 318 ÷ 354 [mm]
  - Depth 800 [mm]
- RGB-D camera acquires image of the scene

Hardware

qbMove

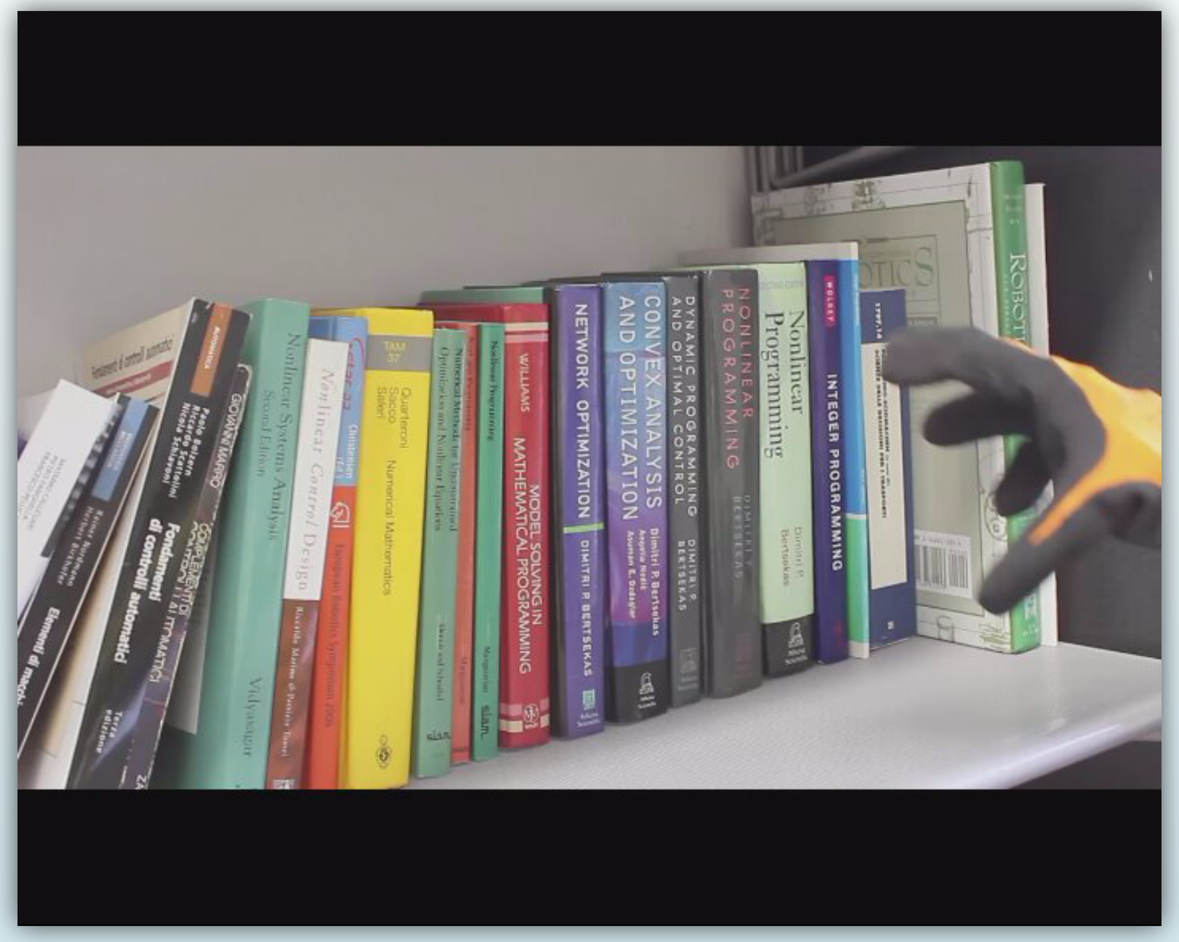
- Variable Stiffness Actuator by qbRobotics
- Stiffness modulation continuously at runtime

Hardware

Pisa/IIT SoftHand

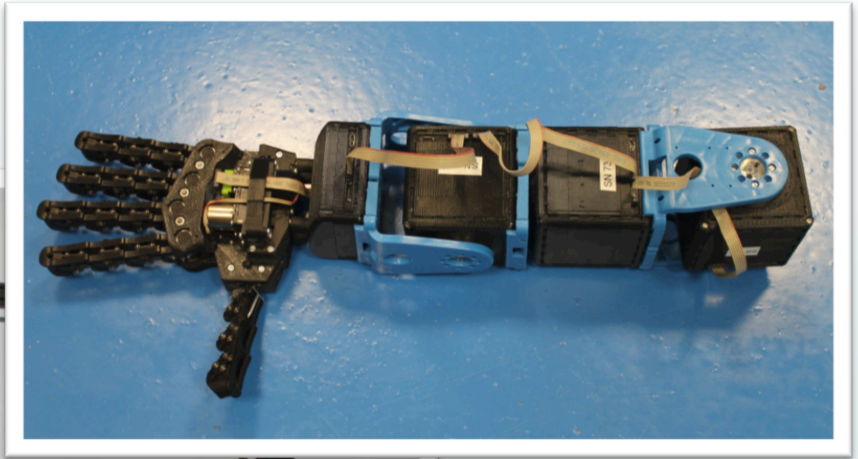
- Under-actuated Soft Gripper
  - 19 DOFs and 1 motor
- Good adaptability at grasping
- Strong robustness under deformations

The Pisa/IIT SoftHand



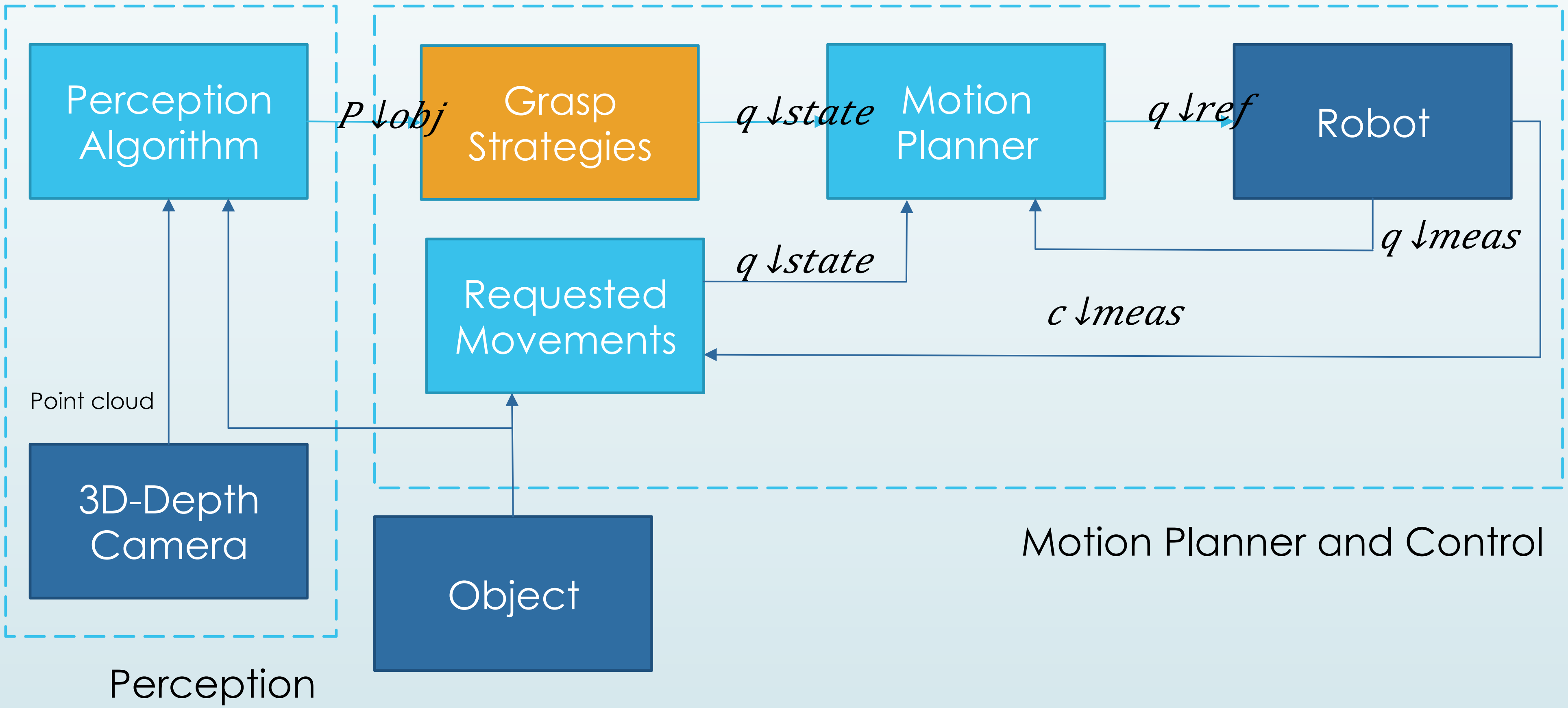
Robot components

- 3 Prismatic Joints
  - 1° motor Z axis
  - 2° motor X axis
  - 3° motor Y axis
- 3 Rotational Joints
  - 4° VSA, Yaw
  - 5° VSA, Roll
  - 6° VSA, Pitch
- RGB-D camera

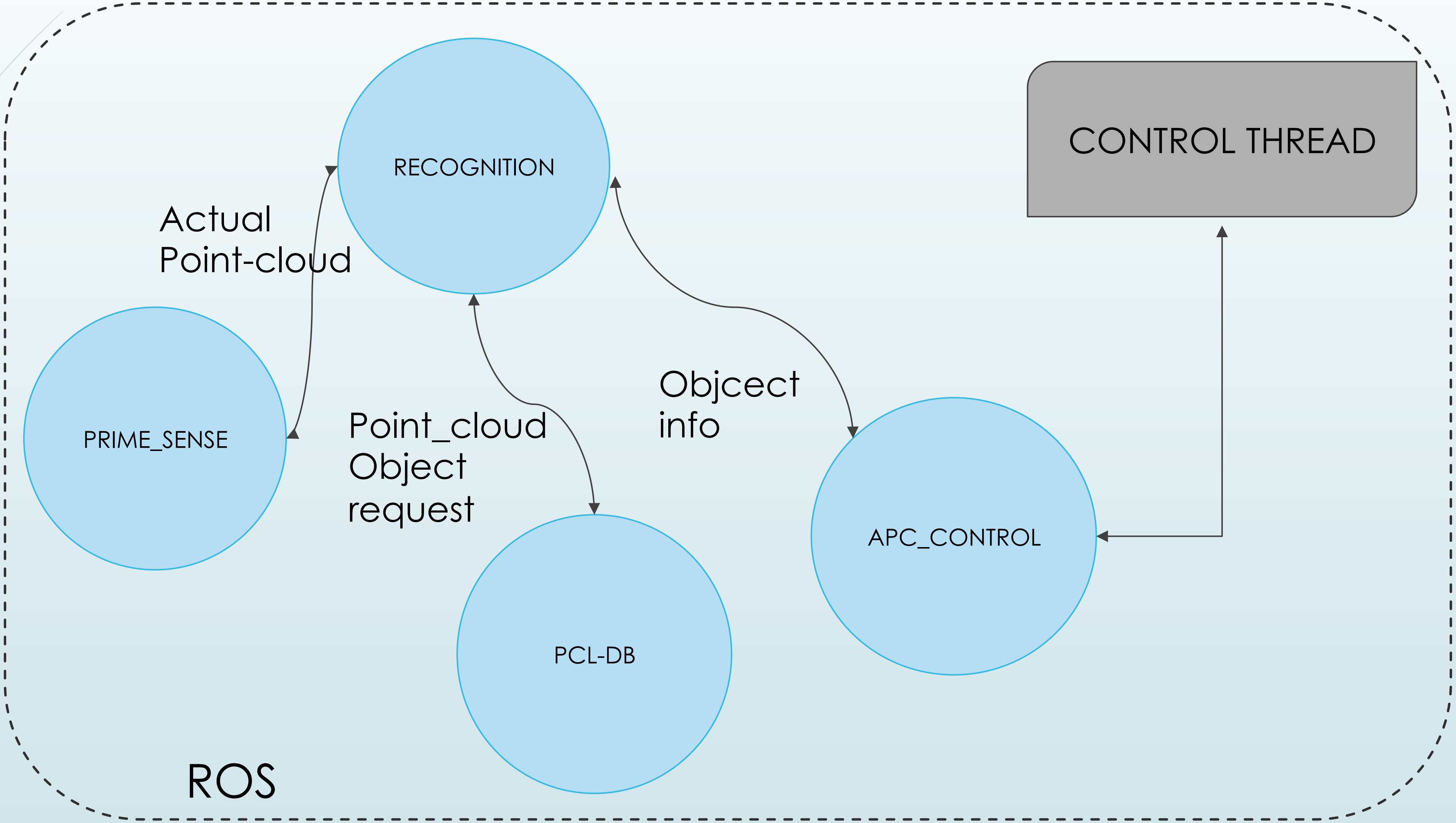


A Motion Planning Algorithm that exploits environmental constraints

Logical Architecture



Software Architecture



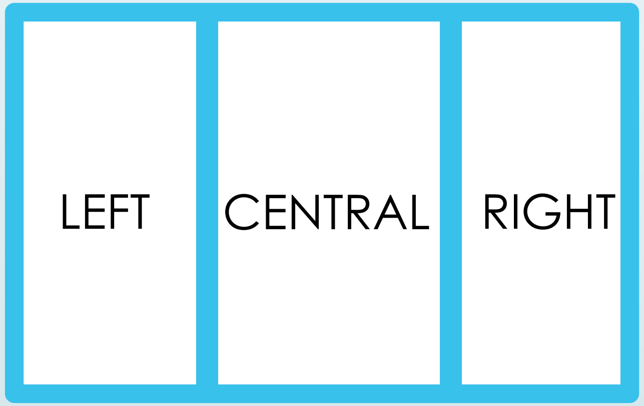
Grasping Strategies

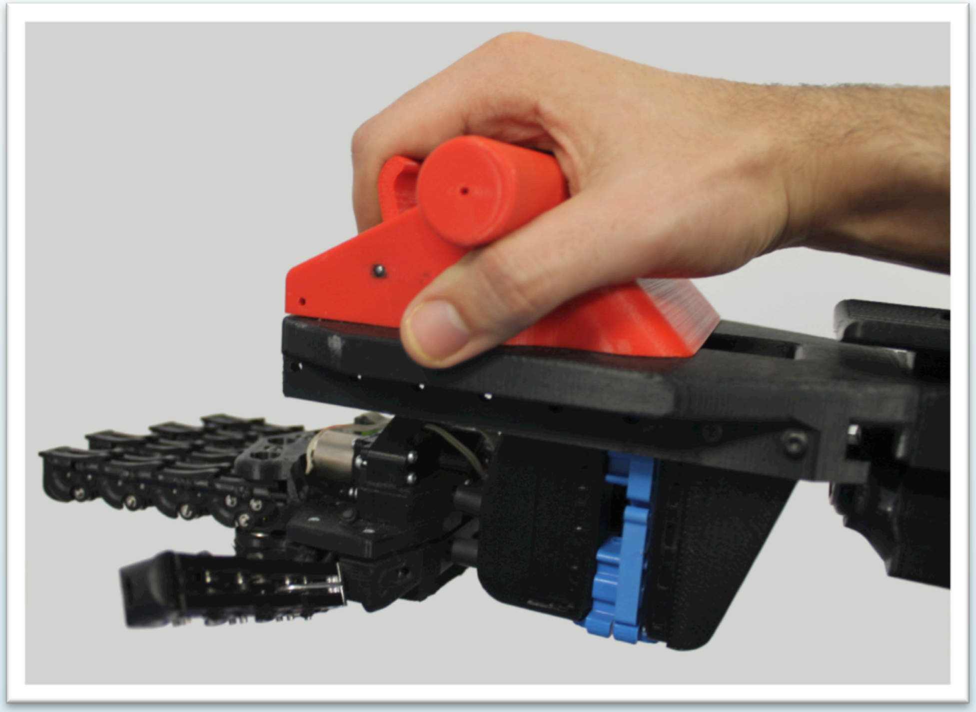
- Usually calculation of the best grasp strategy for an object is complex
  - Grasping can be unfeasible
- Humans solve grasping very easily
  - Exploiting environmental constraints
- Observing how humans grasp objects, we classify and cluster grasp strategies depending on the objects characteristics

Empirical experiments with a handle → Grasp strategies classification → Implementation of grasp strategies

Grasping strategies: Experimental set up

- Scenario was divided in three sectors
- Operator used handle to directly grasp objects with the hand





Grasping strategies: Set of Objects

Grasping Strategies: Experiments

- Object poses table

Object/Orientation	0°	10°	…	360°
oreo_mega_stuf	3	3	…	3
champion_copper_plus_spark_plug	3	3	…	3
…	…	…	…	…
dr_browns_bottle_brush	2	2	…	2

- Each objects is tested in the three sectors
- About 9800 configurations
  - simmetry helps reducing the number of tests to about 1000
- Results were empirically collected

Grasping strategies: Strategy Classifications

Power Grasp

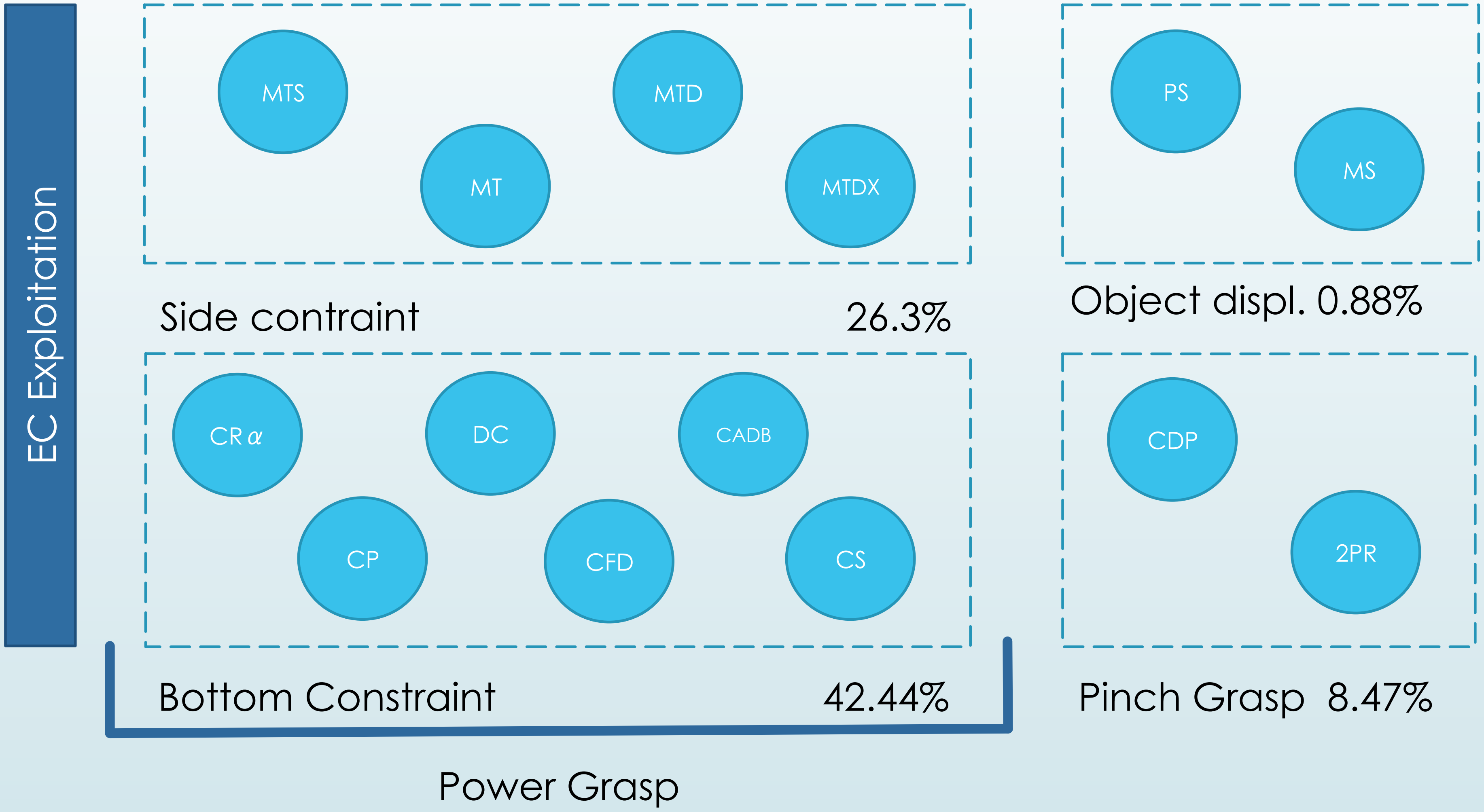
Bottom Constraint

Side Constraint

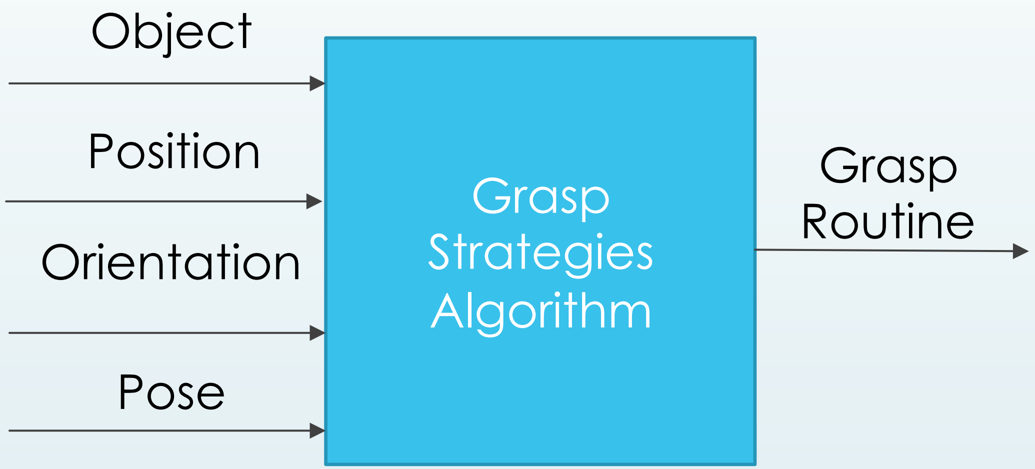
Pinch Grasp

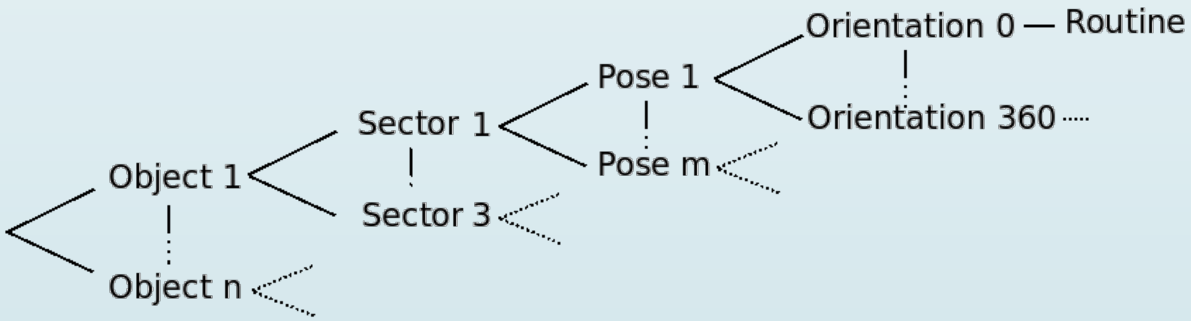
Object displacement

Grasping strategies: Strategy Classifications



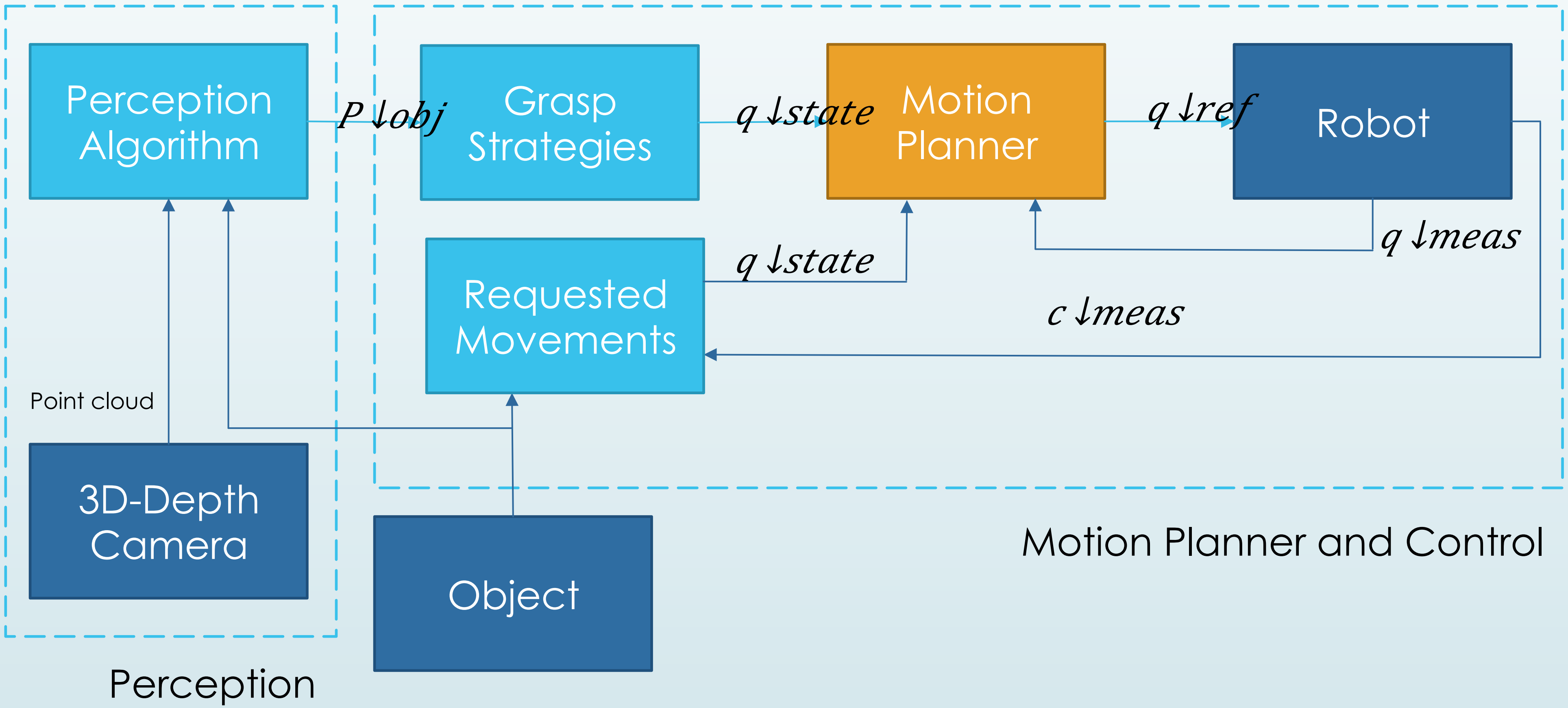
Grasping Strategies: Decision Algorithm





- Results are stored in a Database
- Object position, orientation and pose are estimated by the perception routine
- A decision tree approach is used to decide among all the grasping strategies which one is the best suitable for the current task

Logical Architecture



Motion Planner

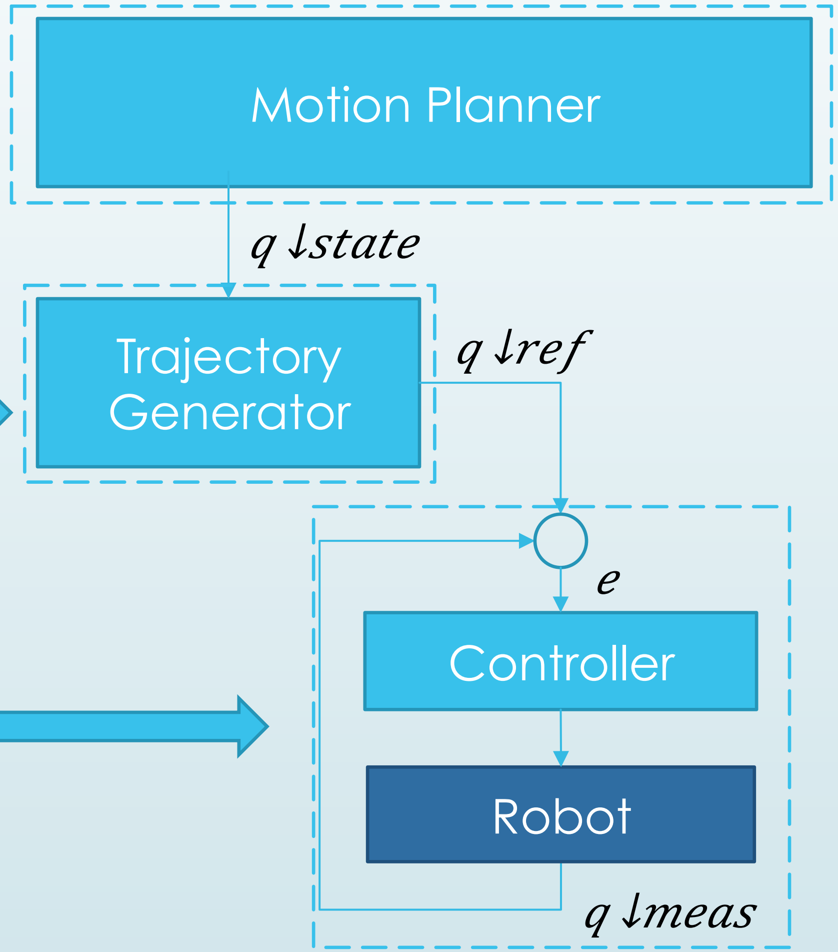
- Several motion planners already exist in literature but most of these algorithms look at the environmental constraints as obstacles
  - Standard collision avoidance
- Motion planner requisites to exploit EC in the scene
  - We need flexible motion planner that allows interaction between robot and external environment
  - Gathering and executing two or more actions in sequence
  - Be fast as possible

Motion Planner

- Store *Annotated Way-Points*

- Generate a trajectory that connects point to point the states saved

- PID controller controls position of the joints
  - Saturation are enabled to increase environmental constrain avoidance when requested

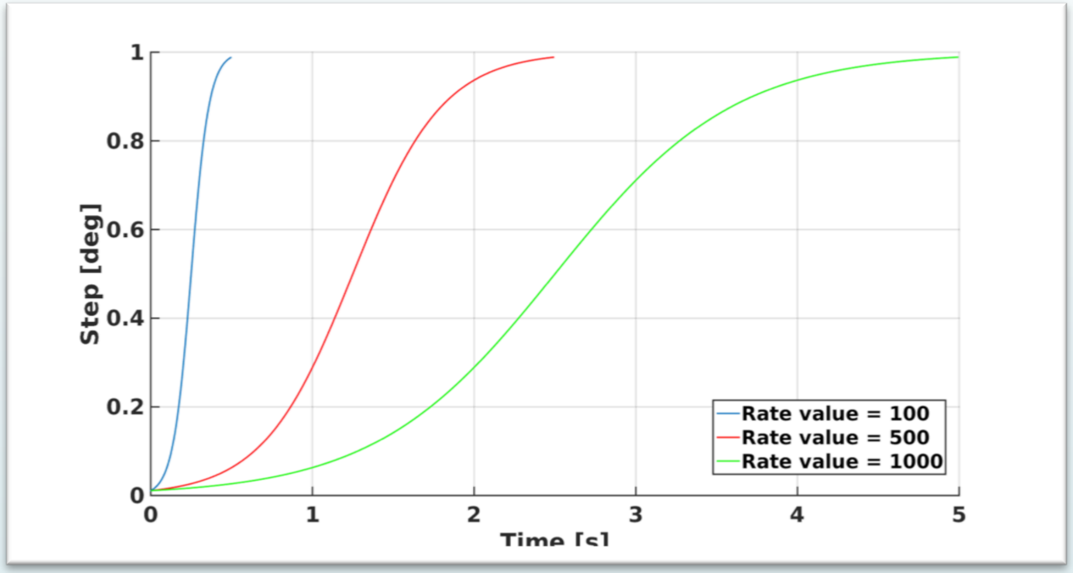


Motion Planner: Rich Way-Points

- Motion planning algorithm is based on the generation of annotated way-points
- Annotated way-points gather several information
  - The desired robot configuration
  - The moving method
  - The hand closure command

Trajectory Generator

- Interpolates all way-points
- Arrival time is the same for all joints
- Generates joint reference positions
  - Modulation on speed profile
  - Set of maximum avilable velocity



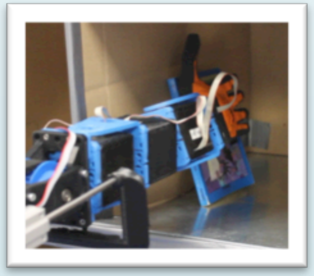
Experiments with the Robot: Set up

- Locate objects random in the bins
- Acquire image with RGB-D camera
- Extract position, orientation and pose of the target
- Decide for the best strategies
- Fetching the object and place it in an external box

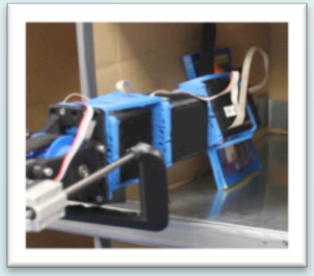
Experiment with the robot

- Robot fetches a book from the left side of the bin experiments

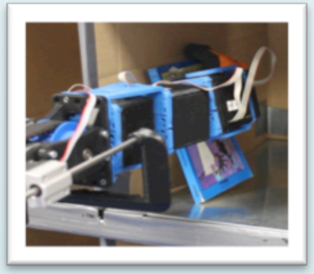
Phase 1: Decision strategies



Phase 2: Approach



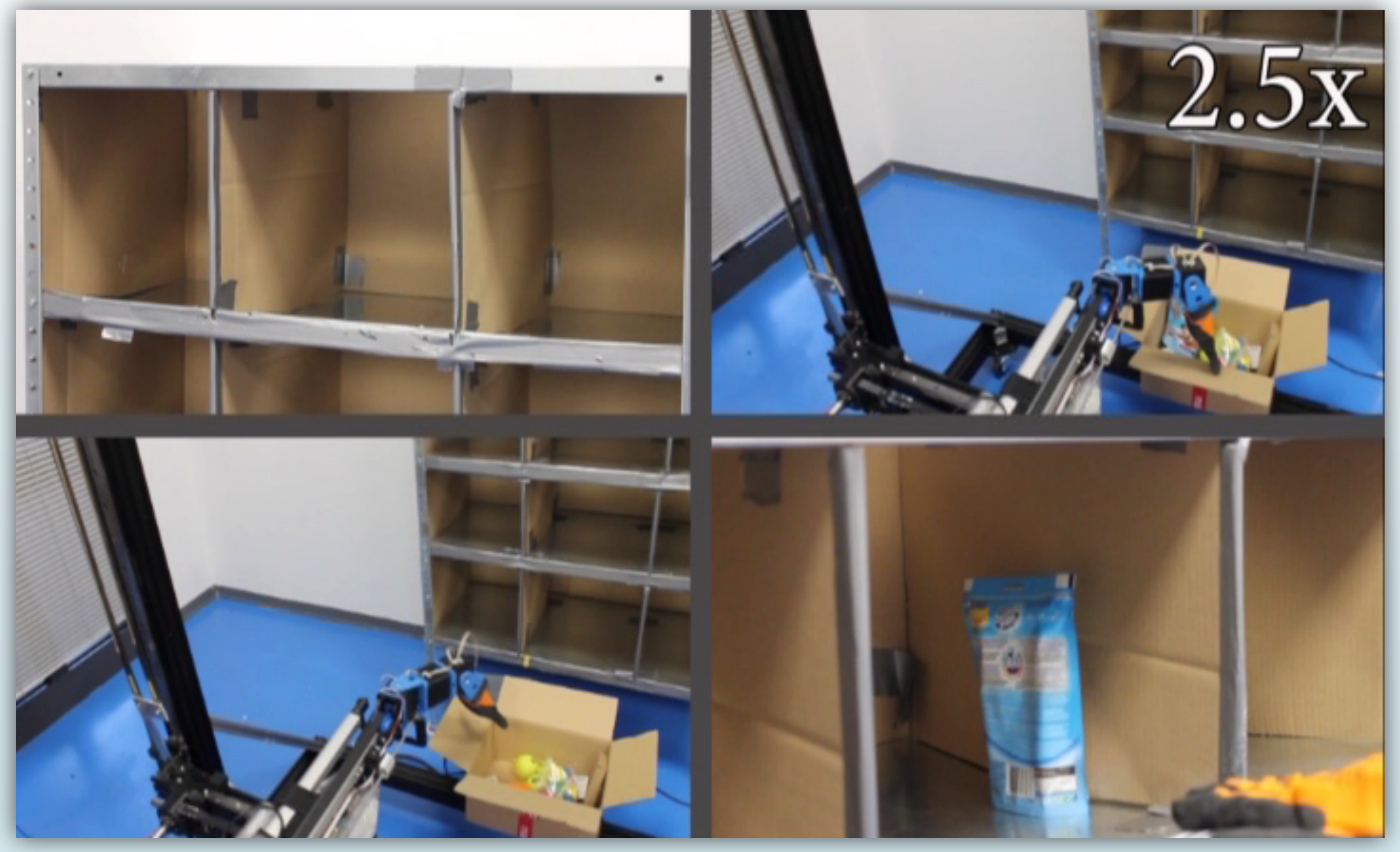
Phase 3: Set Pitch preset



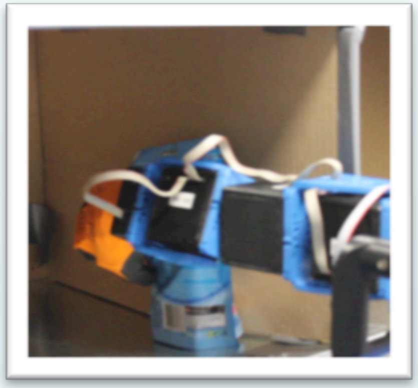
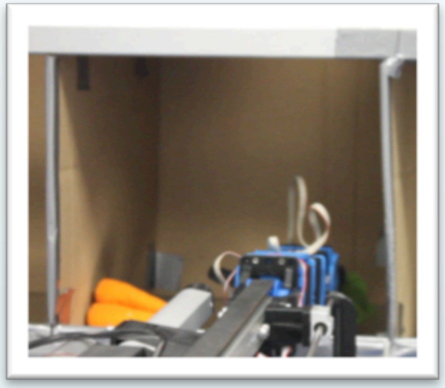
Phase 4: Grasp

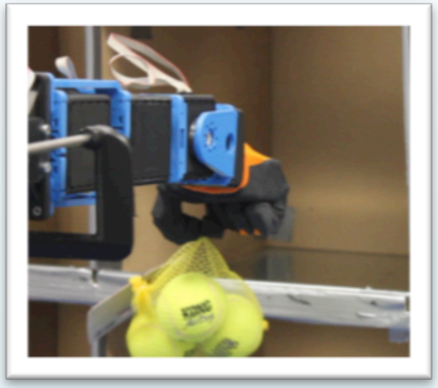
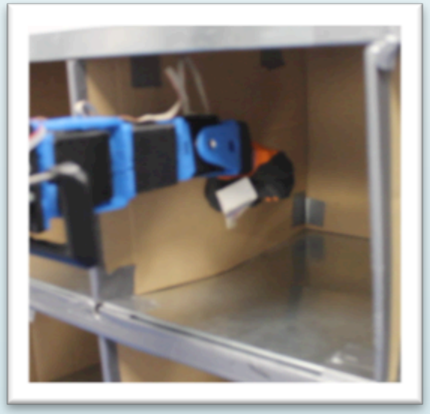
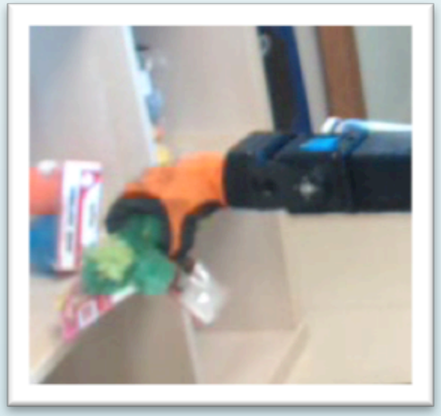
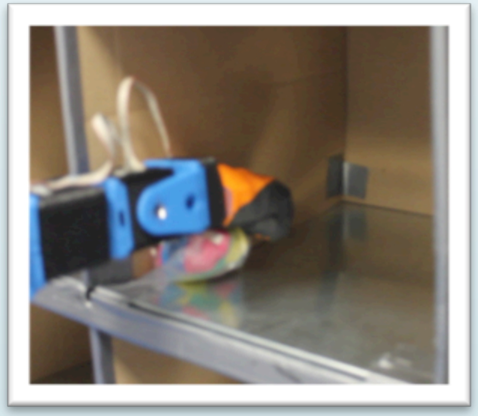
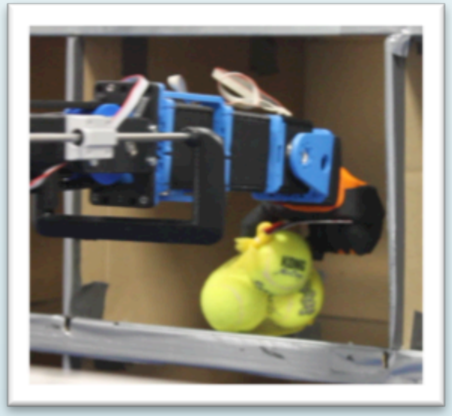
Phase 5: Take out

Further Experiments



Experiments with the robot

Automatized Experiment

Sequence in JSON file:

genuine_joe_plastic_stir_sticks

kong_duck_dog_toy

kong_sitting_frog_dog_toy

munchkin_white_hot_duck_bath_toy

expo_dry_erase_board_eraser

Automated Experiment

Sequence in JSON file :

kong_sitting_frog_dog_toy
munchkin_white_hot_duck_bath_toy
expo_dry_erase_board_eraser

Conclusion

- A *Pick 'n' Place* manipulator composed of standard DC motors, Variable Stiffness Actuators (VSA), an under-actuated anthropomorphic hand and a RGB-D camera was designed and build.
- A grasp strategy able to exploit the intrinsic system compliance was extracted from observation of experiments on human operators.
- A grasp planner was designed, implementing the grasp strategies devised.
- A full control architecture, integrating the grasp planner with a motion planner, a trajectory generator and a real-time control loop was programmed within a ROS system.
- Soft robotics is a good option. However we still need to adress many challenges.
- Soft robots helps us to deal with erros comming from perception.

Thank you for your attention!

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