Robotic Roommates Making Pancakes - Look Into Perception-Manipulation Loop

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Intelligent
Autonomous
Systems

Motivation

Perception for Autonomous Manipulation:

- So far mostly for mobile pick and place
- What if we move towards everyday manipulation such as making pancakes, folding clothes, etc?

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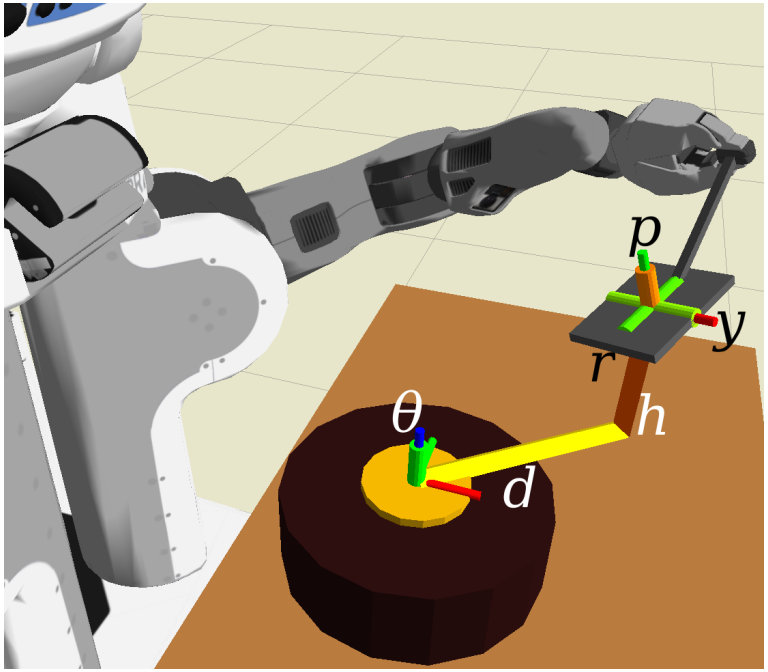
Perception for Pancakes Making



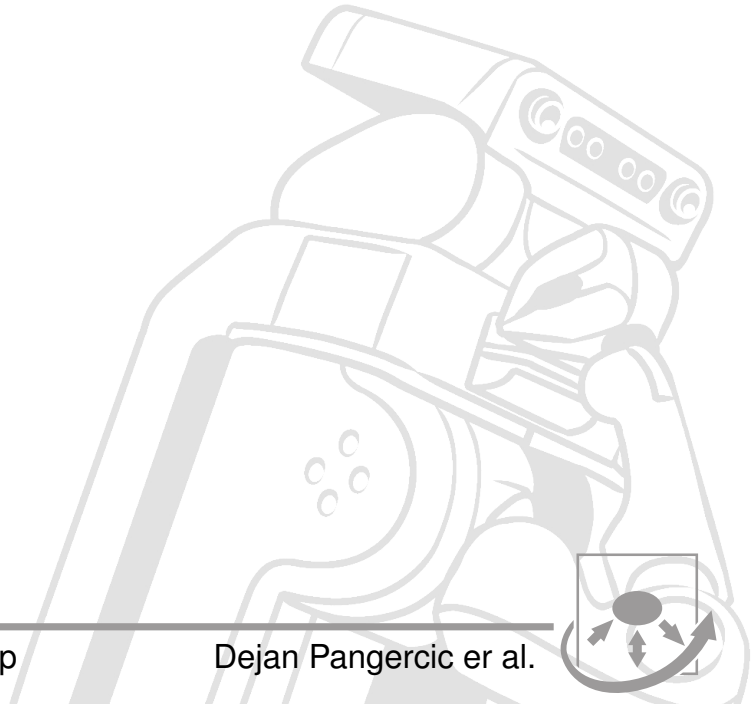
- Localize spatula
- Find stable grasp for spatula
- Calibrate spatula
- Slide the spatula along the oven surface (var. stiffness control as in talk earlier)

Outline

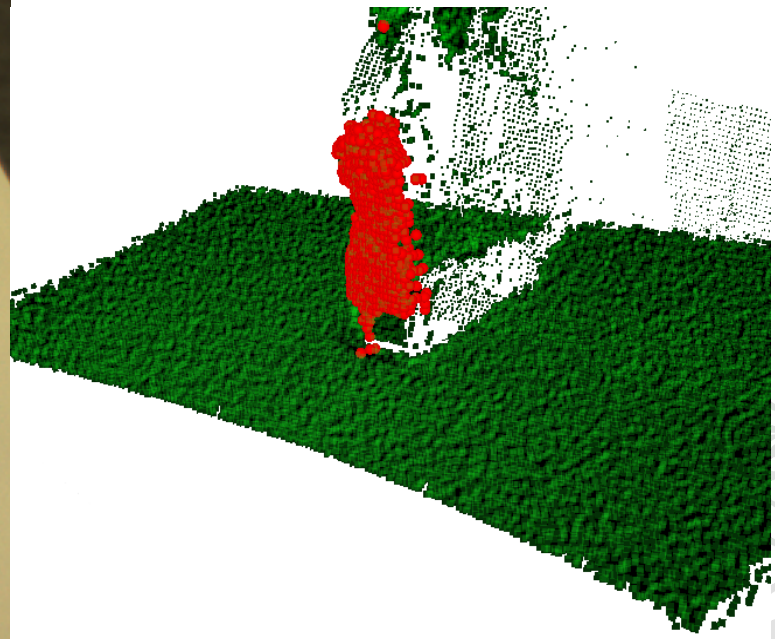
1. Perception-guided Pancake Making

2. Perception-guided Serving

3. Conclusions

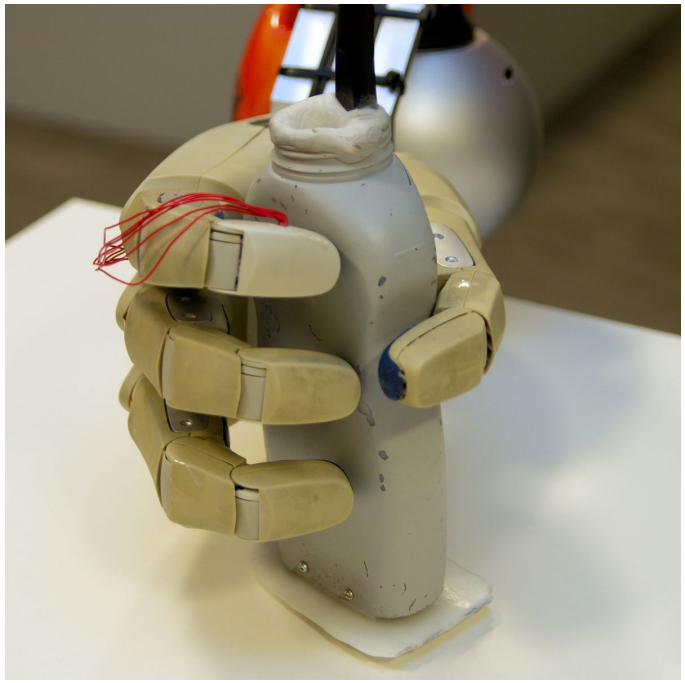


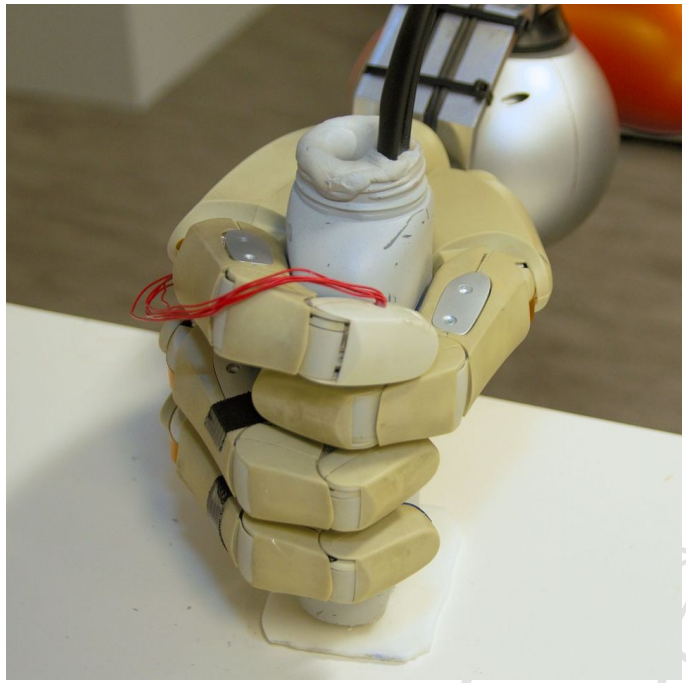
Recognition of Spatula and Pancake Maker



- Oriented point pair features in a given model (Drost, CVPR 2010)

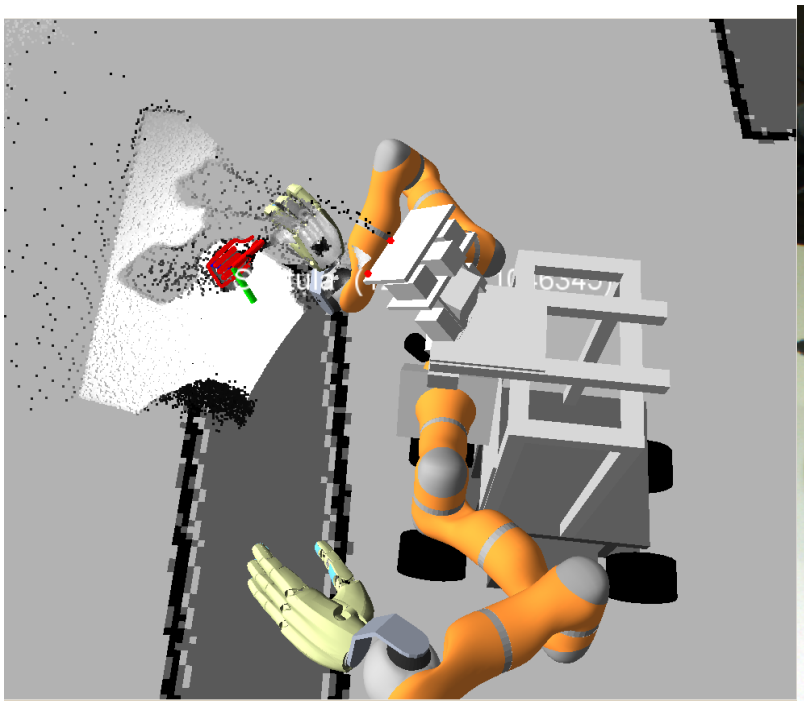
Grasping of the Manipulation Tool

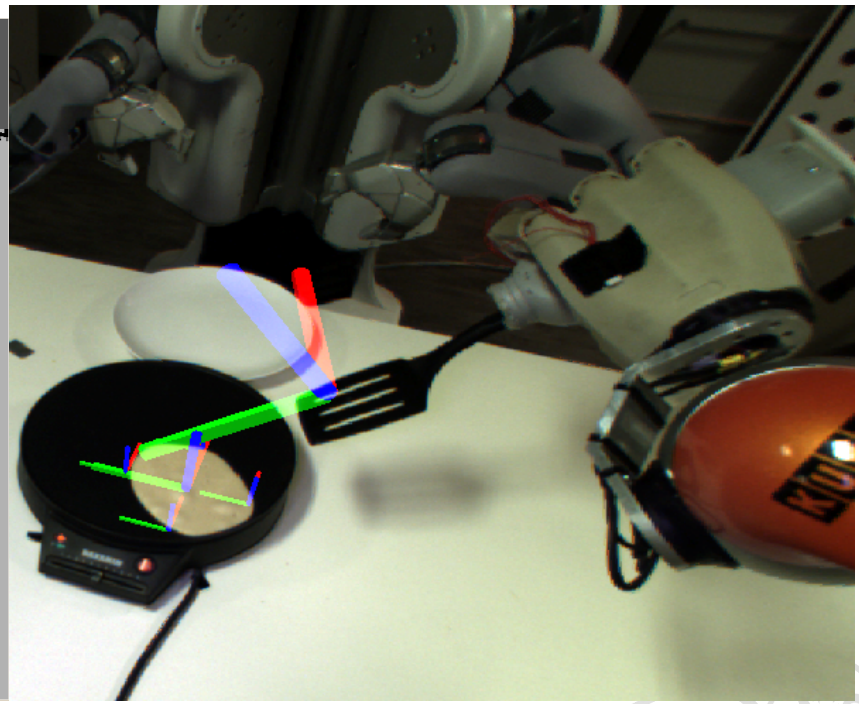




- Measured finger positions and torques
- Data vector distances between current, good and bad grasps as a measure of grasp quality

Calibration of the Manipulation Tool

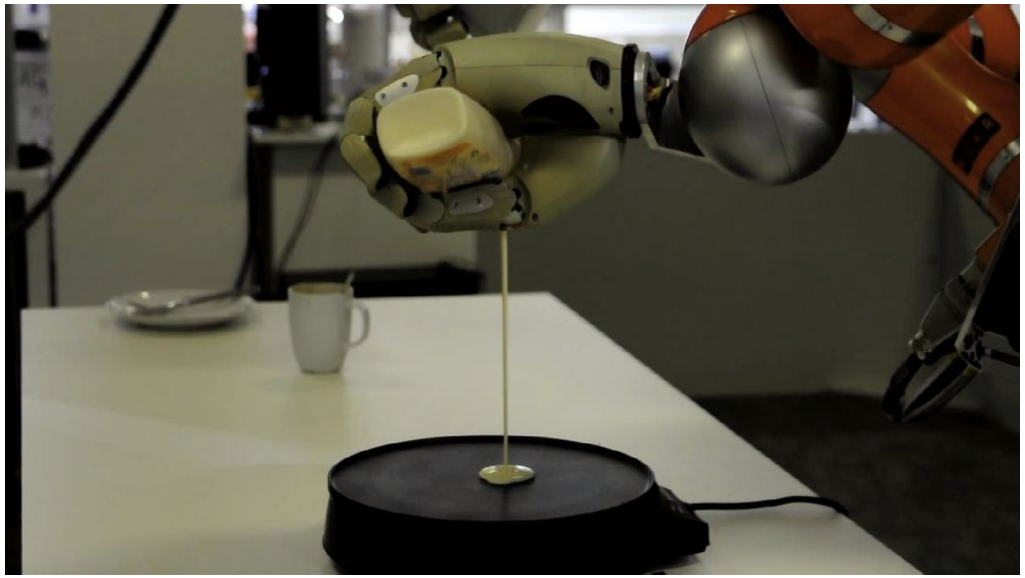




- Planar shape model of spatula
- Edge-based template matching (Hofhauser, VISIGRAPP 2008)
- Cross check through stereo rig

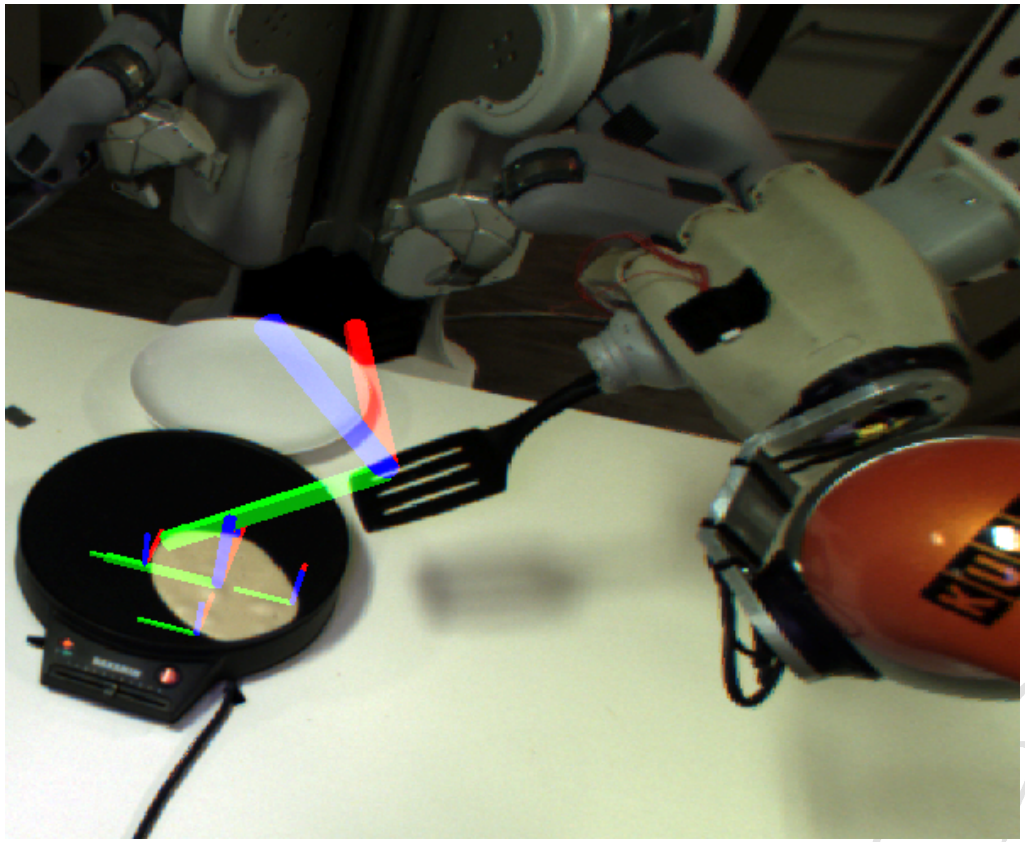
http://www.ros.org/wiki/cop

Pouring of Pancake Mix



- Weight of bottle estimated through measured joint torques
- Height of bottle used for pouring pose
- Pouring time estimated linearly depending on bottle's weight

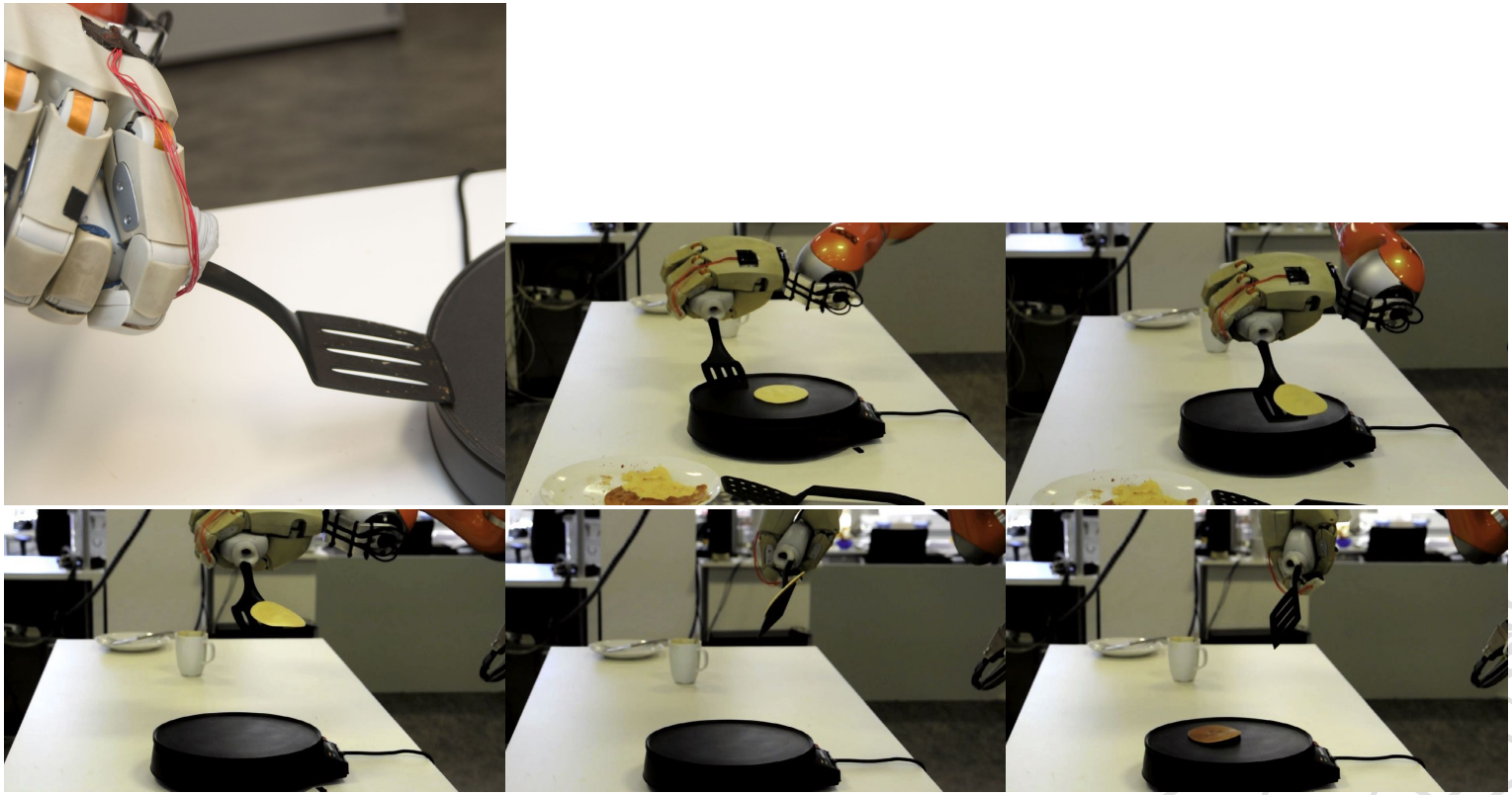
Detection of Pancake



- Color blob segmentation within pancake maker's ROI

http://www.ros.org/wiki/cop

Flipping of Pancake



- Push down till contact with pancake maker detected
- Band pass filter to eliminate constant torques
- Dot product between filtered torques and a template yields peak values
- Flipping movement pre-taught
- Acceleration movements to assure pancake-spatula disjoint

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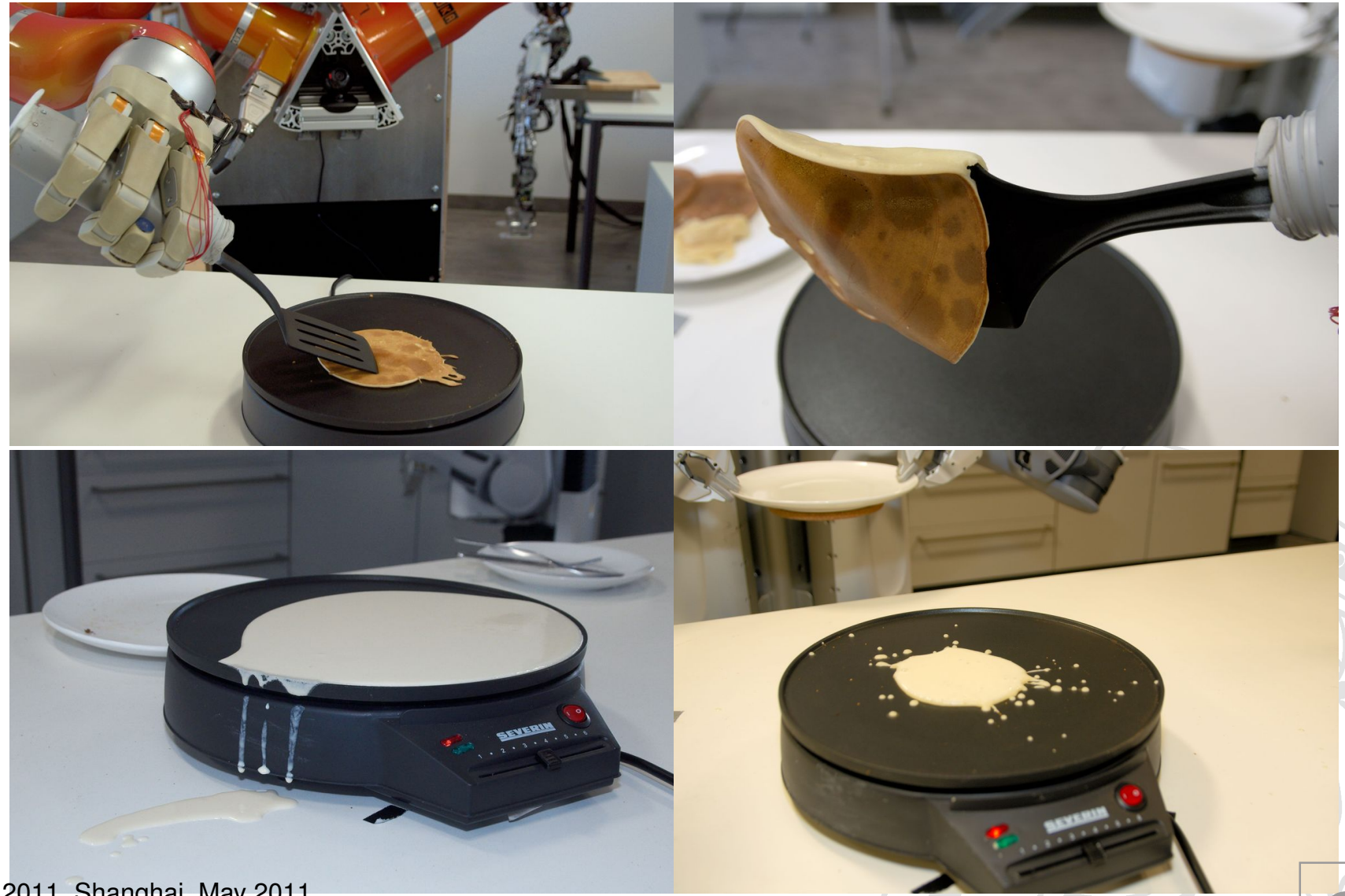
Becoming Failure-aware



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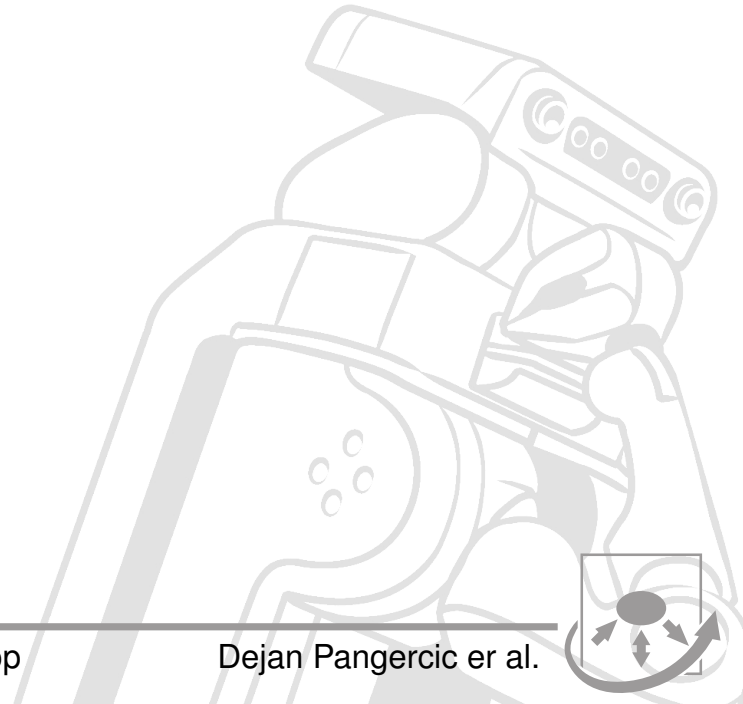
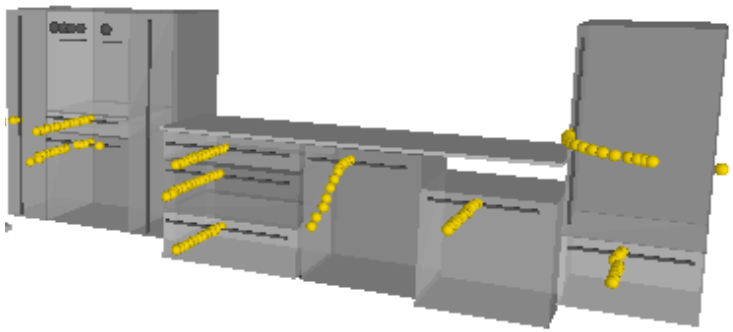
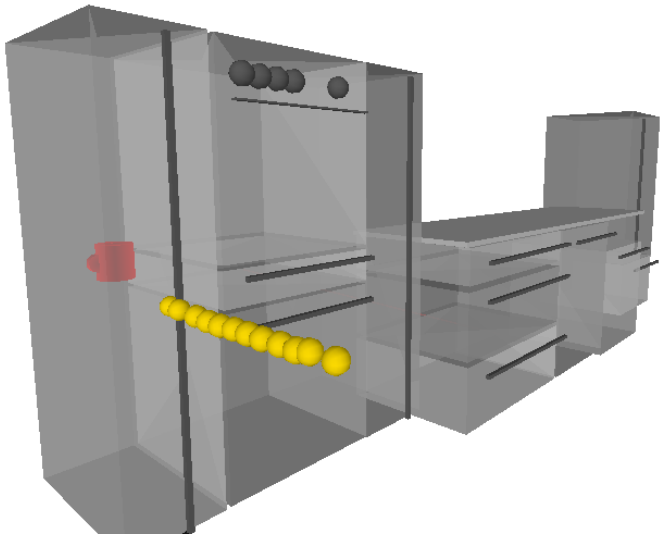


Finding Action Related Places

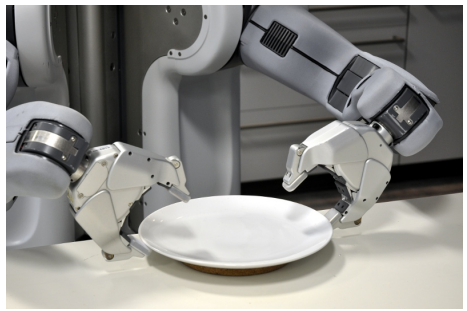


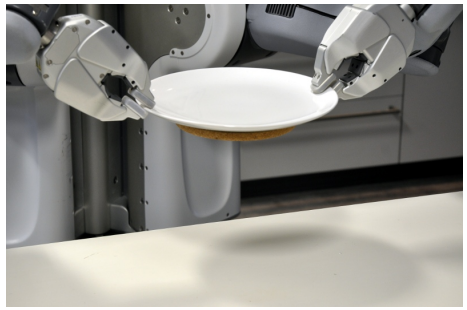


- **“Open the container where cups are stored”**
- Environment map represented in the knowledge base
- Entities of furniture as object instances that inherit properties of their types
- Articulation models for opening containers

Submitted to IROS2011

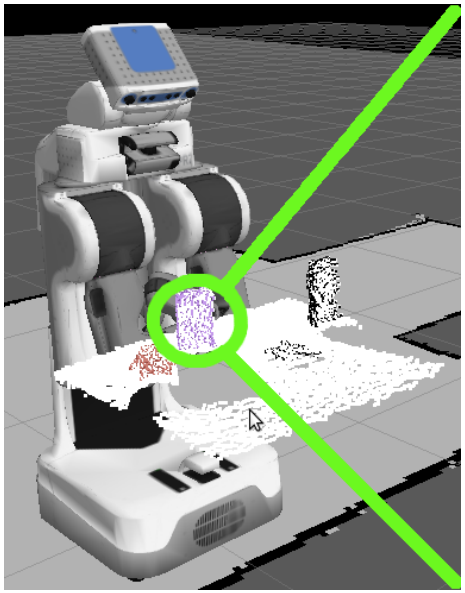
Detecting and Picking-Up Plates



- Circular, continuous edges in RGB image
- Cross check with 3D readings
- Compliant (collision-based) grasp
- Synchronization of arm movements in Cartesian space

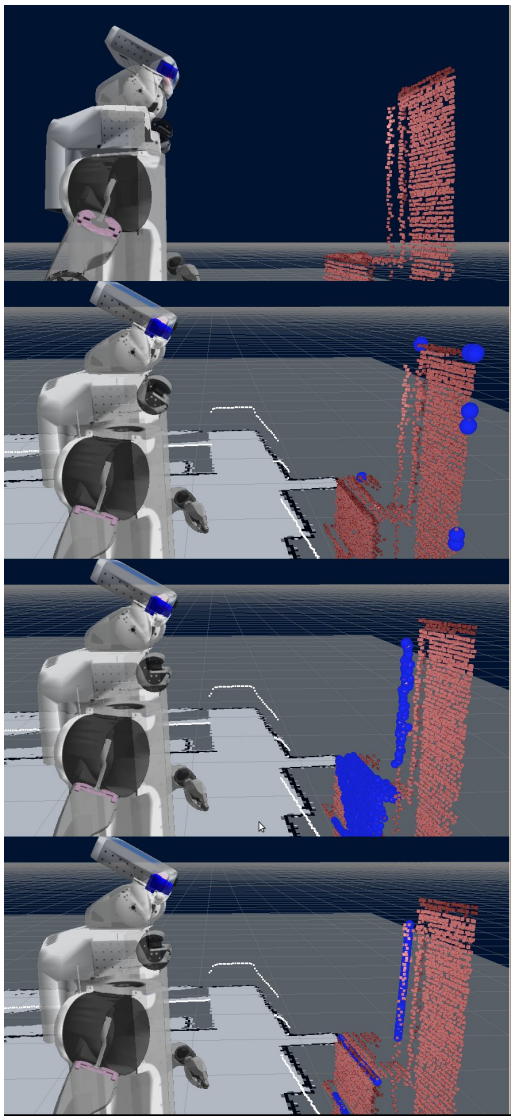
Detecting, Recognizing and Picking-Up Textured Objects



- Combined 2D/3D ROI extraction
- Combination of SIFT and vocabulary trees and TF-IDF
- Templates from www.germandeli.com

http://www.ros.org/wiki/objects_of_daily_use_finder

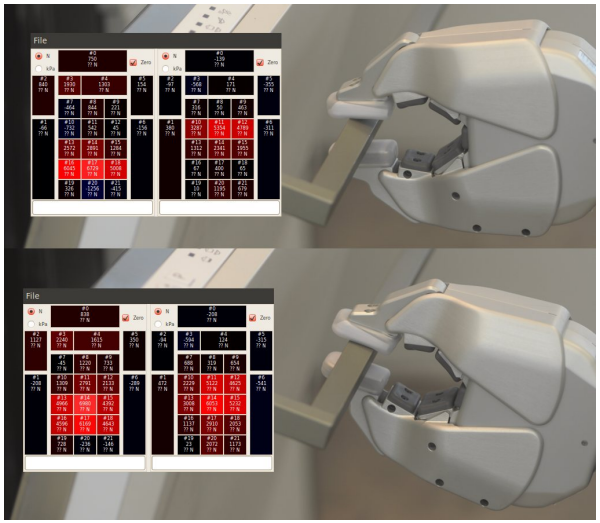
Detecting Handles

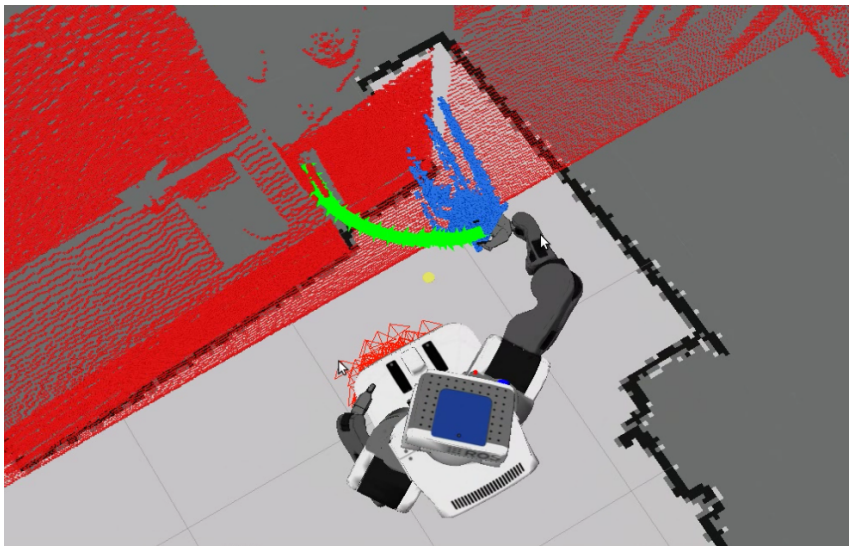


- Fitting of RANSAC planes to front furniture faces
- Segmentation of point cloud clusters within polygonal prism
- Handle's geometric center as grasp point

`http://code.in.tum.de/git/mapping.git`

Opening Doors and Drawers





Initialize pulling direction D from plane normal
while not gripper_slip and cartesian_error $< th = 0.035m$ **do**
  if toolframe close to footprint in (x,y) **then**
    Move base
  Pull with the step-size $0.05m$ in direction D
  Stabilize grasp
  Calculate transform T between pose p_{t-1} and p_t
  Adjust D along transform T
Return $P\{p_0 \ldots p_n\}$.

`ROSpackage:ias_drawer_executive`

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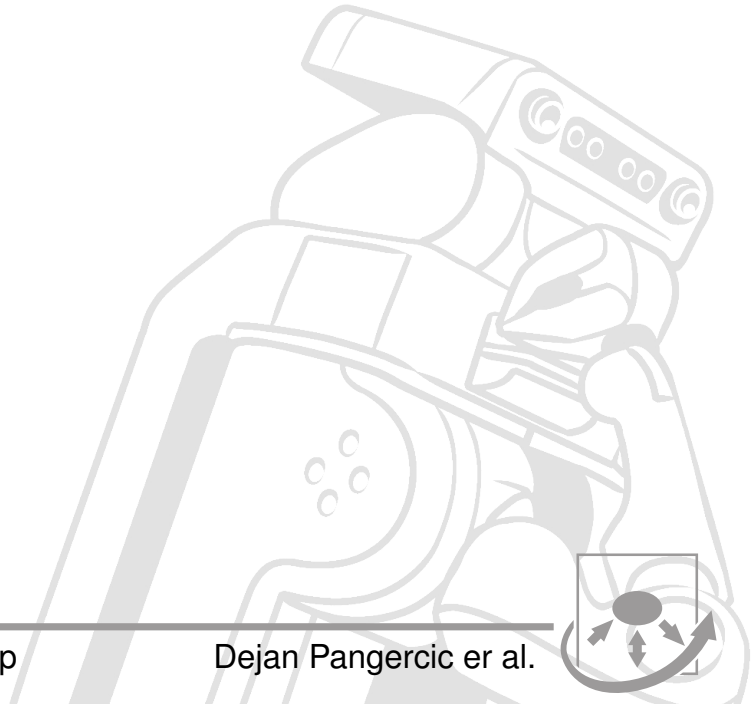

Lessons Learned

- “Amount” of perception needed depends on the robot’s skills and capabilities
- Set of 5 detection routines to solve this complex problem - high initial effort but also highly reusable
- Interplay between proprioception and 2D/3D perception
- Tasks with the real time constraints, e.g. burning pancake
- Trick-to-treat - unforeseen events impossible for motion planner to account for
- Generalization of plan schemata through understanding of (at least) naive physics
- System has run over 100 times since Fall 2010

Open Questions

- Action specific plan schemata rather than general perception system
- Generality lies in automatically deriving perception tasks from reasoning about knowledge pre-conditions
- Part of perception task can be generated automatically (value, no-value operator (as in talk earlier))
- Stability of grasps for human intended objects (e.g. how to perform the same action with PR2)
- Predictive monitoring (e.g. predicting the outcome of pushing action based on the observed deformations of the pancake)

Questions

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`http://ias.cs.tum.edu`

TUM ROS Package Repository:

`http://www.ros.org/wiki/tum-ros-pkg`

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Transfer

- 2D map
- 3D environment map
- Models of objects for perception
- Compliant robot arms
- Base and arm controllers in Cartesian space