A research of autonomous loading / unloading of consumer products using a dual-arm robot

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Towards Easy-to-use, Robust robot platform
Loading Task in Warehouse
Amazon Picking Challenge 2016

- x5, Stowing pet-food bowl and brush
Unloading Task in Warehouse
Amazon Picking Challenge 2016

- x5, Picking gloves

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Loading Task in Convenience Store
Japan Robot Week 2016

- x6, 461/518 picking and 453/471 placing for 8 hours x 3 days

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Problem: How to manage consumer products?

- Amazon Picking Challenge, RoboCup@Home, World Robot Summit, etc...
- Handling various objects in various domains
  - Warehouse, Home, Convenience Store...

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Configuration of Loading / Unloading Task

Warehouse (APC2016)
- Many Categories
- High Workspace
- Cluttered Goal

Store (JRW2016)
- Multiple Objects
- Sorted Goal
- Low Workspace

Differences: change hardware configuration
Commons: make framework
Dual-arm robot AERO

- Using different lower body and end effectors for each different situations
System Structure of AERO

- All actuators are connected via CAN bus using 4-pin connectors
  - Smart actuator: with motor driver and communication board
  - Easy to replace end-effectors
- Completely separated upper / lower body
  - Easy to replace body part

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Common Solution of Loading / Unloading Task

- Object Recognition: Classify What, where it is
- Localization: Where to move, Where to place
- Planning: How to pick, move, and place

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Warehouse Task
Amazon Picking Challenge 2016

- Motivation: to Handle various objects by our robot system
  - Small body
  - Simple gripper and external vacuum

- Solution: Fully Model-based Planning
  - 3D geometrical model using EUSLISP
  - Classifier using cloud service

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Object Segmentation (Stow task)

- Super Pixel segmentation for 3D image
  - each super pixel are grouped using normal
- Robot tries to grasp center of top side region

Warehouse

Input 3D Image

Normal Estimation

Connected super pixel using normal image

Extract top side region

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Object Recognition (Pick task)

- Segmentation: same as the stow task
- Classification: using Microsoft Azure Cloud based on COCO dataset
  - Classifier does NOT return object itself but returns COCO’s 80 categories
  - ex) bear: “brown”, “teddy”, “bear”...
Geometrical Modeling for grasp planning

- Classify 38 categories by shape manually
  - Box: 18
  - Cylinder: 8
  - Ball: 1
  - Complex: 7
  - Deformable: 4
- Define grasp pattern for each object shape

Warehouse

All Objects

Geometrical Models using EUSLISP

Cylinder: Arrowing rotation by center axis

Box: Arrowing rotation at contact point

Thin Object: Contact suction cup vertically to wide plane

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Collision Avoidance to Shelf

- 3D geometrical model of Kiva pod is also created in EUSLISP
- Collision check is applied for each plates
  - when collision detected, change waist position to opposite direction

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Convenience Store Task
Japan Robot Week 2016

- Motivation: to sort multiple objects
  - long-term test
    - for 8 hours, continuously
    - total 24 hours

- Solution:
  - Model-less planning
  - Model-less recognition
Localization

To localize robot position, recognize shelf plane and edge from 3D point cloud

- direction is detected by plane segmentation
- position is estimated by edge

Warehouse

Model-based (for short distance)

Detect edge points

Vote up points

Set shelf edge

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Empty place finder

- Sorting objects facing front side
- Finding empty region to place
  - No information about placed objects
  - Object independent solution using saliency map

Input Image

Crop bin region

Calc Saliency from RGB

Saliency Map

Clustering

Reject small / far clusters

Grid mapping

Occupancy Grid

Calc X distance of regions

Empty Region

Store

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Grasp planning using shape

Object classification is based on aspect ratio (width and height)

To absorb misalignment, pushing bottom face to shelf plate
- misalignment is caused by diff of cog and recognized position

Pushing motion increases successful rate from 81% to 93%.

Grasp and Place planning

Without pushing  With pushing
Conclusion

- We defined loading / unloading task and propose its solutions with different 2 configurations.
- It is most important to choose solution can adopt new scenes with low cost.
  - In APC2016 we implemented object models one by one and spent much time.
  - Reflectively, in JRW2016 we choose model-less solution.
- Next Challenge: to handle Fragile Objects
  - World Robot Summit 2020