Team NAIST-Panasonic

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Team NAIST-Panasonic = 20 Members
Outline

• Lessons from the past
• New challenges
• Suction force analysis
• Storage system
• Conclusion
Lessons from the past
Failures examples

- Recognition failure
- Unexpected collision
- Grasping approach
- Item loss
## Failures and potential impact

<table>
<thead>
<tr>
<th>Failure</th>
<th>Potential impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collision with storage system</td>
<td>Round loss</td>
</tr>
<tr>
<td>Planning failure</td>
<td>Round loss</td>
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<tr>
<td>Items left on recognition space</td>
<td>Object recognition capability loss</td>
</tr>
<tr>
<td>Losing suction contact</td>
<td>Point loss due to dropped item</td>
</tr>
<tr>
<td>Two-item grasping</td>
<td>Point loss due to lost item</td>
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<td>Object recognition errors</td>
<td>Point loss due to misplaced item</td>
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<td>Grasping failures</td>
<td>Time loss</td>
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<tr>
<td>Slow path-planning</td>
<td>Time loss</td>
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</tbody>
</table>
Lessons from the past

Hardware
- One 7-DOF manipulator can suffice
- 7-DOF can be faster than 6-DOF manipulator (shorter joint space distance)
- Suction tool worked for 80% of the items
- Professional suction system needed for reliability
- Sensor stability issues possible

Software
- Learning-based object recognition has high success rate
- Depth information may not improve object recognition
- Illumination significantly affects object recognition (RSJ review)
- Datasets can be used (Team C^2M, Team R U Pracsys, Team MIT-Princeton)
- MoveIt planning speed can be prohibitive

Strategy & Workflow
- Failures are unavoidable → Error recovery is essential
- State machines effective for task planning (Team Delft)
- Do not modify the code in the last minute (!)
New challenges
New Challenges in ARC 2017

- Half of items unknown until 30 min. before round
  - Too short to gather data and train
- New design dimension: Storage system
  - Storage system can be adapted to robot
- Storage system volume significantly reduced
  - 30% (!) of previous years’
  - Increased occlusions and stacked items

**Our requirements:**
- Object recognition using pictures and models supplied by Amazon (not only learning-based methods)
- Maximize surface of storage system to minimize clutter
- Catch and fix errors during the round to compensate for uncertainty
Suction force analysis
Suction tool model

\[ F = \Delta p^* (A_p - A_o) \]

- Perfect contact: \( A_o = 0 \)
- No contact: \( A_o = A_p \)

- \( Q \): flow rate
- \( p_a \): atmospheric pressure
- \( p_s \): internal static pressure
- \( d_t \): tube length
- \( A_v, d_t \): tube cross section area / diameter
- \( A_p, d_p \): suction cup cross section area / diameter
- \( A_o, d_o \): opening cross section area / diameter
Suction force

\[ 20 \text{ N} \approx 2 \text{ kg static weight} \]

Experimental limit

Safe zone

Max force

Air flow

Contact

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Suction tests

With $d\downarrow p = 40\ mm$ and $d\downarrow t = 30\ mm$:
- 36 items can be suctioned (90%)
- 9 items can be potentially damaged (22.5%)

Successfully suctionable items include:
- Marbles
- Measuring spoons
- Bath sponge
- Dumbbell (with a lot of luck)

Unsuccessful:
- Mesh cup
- Brush
- Scissors
Storage system
Storage System

Rules:
• 2-10 bins
• 95,000 cm$^3$ bounding box
• Up to 32 items
• Max: 42 x 27 x 14 cm
• No actuators
• Sensors < 50 USD

Volume is 30% of previous years!
Original design:

- As shallow as possible
- Easy to change bin sizes
- Many partitions to increase available surface

→ Maximize used volume, minimize clutter

v1

v2 (after item size increase)
Storage System
Loading test

Empty

Filled

Still too cluttered!
Conclusion
Conclusion

• Systematic listing of potential failures and their impact
• Summarized good practices, heuristics and data from the past
• Showed the importance of storage density
• Suction force analysis and tests
  → Larger hose diameters and flow stabilize suction contact
Thank you for your attention

See you in Nagoya!