Grasping Approach

“Put the fingers on the right place”

Assume Complex Hands

“Let the fingers fall where they may”

Expect Simple Hands
Let the fingers ...

“Hand conforms to object”

Passive Adaptation

“Object conforms to hand”

Passive Sensing
Bin-Picking

- High clutter.
- High pose uncertainty.
- Goal: Singulation.
- Simple Hand
  ✓ Singe actuator.
  ✓ Thin, hard compliantly coupled fingers.
  ✓ Low friction.
Bin-Picking

- Blind grasp.
- Grasp signature.
- Success/Failure.

- Success ratio 42%

\[ \tau = 2.17 \]
We can do better
Probability of Success

• Data driven model of instantaneous probability of success.

\[ M : s([0, t]) \rightarrow p(t) \]

• Relevance Vector Machine.

• Principal Component Analysis.
Abort and Retry

• Threshold the probability of success?

✓ Discretize the system: $S_1, S_2 \ldots S_n$
✓ Instantaneous probabilities: $p_1, p_2 \ldots p_n$
✓ Abort thresholds: $\pi_1, \pi_2 \ldots \pi_n$
✓ Transition probabilities

$$P_i = P[S_i \rightarrow S_{i+1}]$$
Abort and Retry Model

- Markov Chain

\[ R \]

\[ 1 - P_1 \]

\[ 1 - P_2 \]

\[ 1 - P_n \]

\[ 1 \]

\[ P_1 \]

\[ P_{n-1} \]

\[ P_n \]

- Transition cost \( \Delta t \)

- Abort cost \( R \)
Time Successful Grasp

\[ \tau = \Delta t \left[ 1 + \sum_{i=1}^{n-1} \left( \prod_{j=1}^{i} P_j \right) \over \prod_{i=1}^{n} P_i \right] + R \left[ 1 - \prod_{i=1}^{n} P_i \over \prod_{i=1}^{n} P_i \right] \]

- Estimate first \( P_i \) to estimate \( \tau \)
  - Given N grasp executions.
  - Choose thresholds.
  - Estimate \( P_i = \frac{\text{Grasps reach } S_{i+1}}{\text{Grasps reach } S_i} \)
  - Compute \( \tau \)

- Off the shelf direct search optimizer.
Implementation

- ROS

- State machine that implements the Markov Chain.
  
  ✓ Robot controller.
  
  ✓ Grasp controller.
  
  ✓ Vision interface.
  
  ✓ Learning interface.
## Results

<table>
<thead>
<tr>
<th>$n$</th>
<th>$\tau$</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.17</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>2.12</td>
<td>4.3%</td>
</tr>
<tr>
<td>4</td>
<td>1.98</td>
<td>16.5%</td>
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<tr>
<td>8</td>
<td>1.91</td>
<td>22.0%</td>
</tr>
<tr>
<td>16</td>
<td>1.58</td>
<td>50.4%</td>
</tr>
</tbody>
</table>
Take Home Message

• Simple Hands are less capable than Complex Hands but more capable than we think.

• Use proprioception to observe the grasp process.