Industrial robot programming by demonstration

Dr. Rong XIONG, Dr. Jiafan ZHANG
Email: rxiong@iipc.zju.edu.cn, Jiafan.zhang@cn.abb.com
Where we are from
Zhejiang University, Hangzhou, China

Zhejiang University
- Founded in 1897
- Top 3 in China
- 23,000 undergraduate & 22,000 graduate students
- About 3400 faculties
What we are focusing
The State Key Lab. of Industrial Control & Technology

Humanoid robots playing table tennis
- Advanced motion control
- Lightweight structure design
- High speed vision system
- Perception technology

Kidsize humanoid robot for soccer
- Champions of RoboCup since 2013

Small size robot for soccer
- Champions of RoboCup since 2013

Service robot
- SLAM & navigation
- Environment sensing
- Human identification

Serial elastic leg
- Force control
- Compliance control

Kidsize humanoid robot for soccer
- Finalist of RoboCup in 2015
- Domestic champions in steak since 2008
The world factory
Labor intensive, low valued-added, ...
Robots booming in China
The largest robot market in the world

• Largest robot market with 54.6% increased sales in 2014, 25% of the global total
• Government mandates and political encouragement

Chinese manufacturers are currently leading the world in terms of procurement of new industrial robots
Dilemma of robotized production
Not easy to use, esp. for small & medium enterprises

- Traditional robot programming
  - Not intuitive
  - Robotic skill required
  - Repeated and time-consuming
  - Little flexibility
Programming by Demonstration
Robots with intelligence

- To extract as much information as possible from a human demonstration and transform it into an abstract, generalized representation for industrial robots.
Programming by Demonstration
Part Recognition

- Smart vision system for part recognition

YB Wang, RXiong, JF Zhang, et al. ROBIO, 2015
Programming by Demonstration

Assembly graph establishment

- To obtain the assembly sequence and the final assembly relationships of parts

- Compatible to the existing CAD model
- Available to the sub-assembly
Programming by Demonstration
Max probability based assembly graph

Due to vision system error and uncertainties in human operation

The assembly relationship is corrected.

- Y Wang, C Jie, R Xiong, Y. Liu, IROS, 2015
Programming by Demonstration
Assembly graph and skill sequence

To percept the intension of human operator
- Assembly sequence and the assembly constraints
- Skill representing the operating action sequences

A skill is composed of several actions.
Programming by Demonstration
Action definition and skill

- Hierarchy structure of action

- Skill - Network of actions
  For example: The skill of material handling is composed of Picking - Moving - Placing

MH:
Programming by Demonstration
Action identification

- Trained with 100 samples from different operators for each gesture
- The hybrid method with HOG and Zernike moment based on max probability promising a high accuracy of the gesture recognition

- To fully identify an action with gesture, trajectory and the appearance of part in-hand

<table>
<thead>
<tr>
<th>Gesture</th>
<th>Trajectory</th>
<th>Appearance of part in-hand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Placing</td>
<td>Moving downward</td>
<td>Adding part to assembly area</td>
</tr>
<tr>
<td>Screwing</td>
<td>Circling</td>
<td>No change</td>
</tr>
<tr>
<td>Pushing</td>
<td>Moving on a plane</td>
<td>From one position to another</td>
</tr>
</tbody>
</table>

HS Yu, R Xiong, et al. Submitted to ICRA, 2016
Programming by Demonstration
Action identification - Demo

- Placing
- Screwing
- Pushing
Programming by Demonstration
Robot motion translation

Simple robot motion mapping

Action
robot procedure
Robot basic movement

Skill level robot motion translation

Skill sequence
Robot program & cell logic control
Cell running

PROC Pick()
MoveL [[Px, Py, Pz+50], [q1, q2, q3, q4]], v200, z20, Gripper.
MoveJ [[P10x, P10y, P10z], [q10, q12, q13, q14]], vmax, z0, gripper.
ENDPROC

PROC Pick()
MoveL [[Px, Py, Pz+50], [q1, q2, q3, q4]], v200, z20, Gripper.
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ENDPROC
Programming by Demonstration
Demo to assemble a flash light
Programming by Demonstration
Challenges and future work

- Sensing more operation information, e.g. force, tactile, etc.
- The perception of assembly graph with the blind part
- Iterative optimization robot path planning
- Cloud computing for assembly knowledge learning and re-use
Thanks for your attentions!

Welcome to China, and to Zhejiang University!