Thoughts on Robot Assembly Skills and Machine Learning

CASE 2018 Workshop “Robotic Assembly – Recent Advancements and Opportunities for Challenging R&D”
Munich, Germany, 20th August 2018
Questions and thoughts I want to share

What are Robot Assembly Skills?
What is Machine Learning?
What should be Learned, and How?
What are the Major Obstacles?
Intelligent robots
Learn from human intelligence…

Problem solving, decision making, learn, train, …
Smell, see, feel, …
Move, grasp, speak, …

…to create skilled & easy to use robots
Intelligent robots
How they should (not) be

- Copy of human
- Replacement of human
- Universal machine

- Skilled to perform desired tasks (assembly, healthcare, …)
- Can deal with uncertainties and changing situations
- Can learn to perform tasks better (more efficient, precise, …)
- Can be intuitively instructed by human (goal-oriented, natural language or other simple input means)
Robot Assembly Skills
Ability to perform assembly tasks autonomous and proficiently

Example of skills and skill levels
How do humans gain skills
Self-learning and/or with teacher

<table>
<thead>
<tr>
<th></th>
<th>Solution Learning</th>
<th>Method Learning</th>
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<tbody>
<tr>
<td>By Exploration</td>
<td>Try out a numbers of ways and find one or several non-optimal solutions (local optima)</td>
<td>Try to summarize, analyze and structure, based on existing knowledge</td>
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<td></td>
<td><em>Medium, time consuming.</em></td>
<td><em>Weak, time consuming.</em></td>
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<tr>
<td>By Imitation</td>
<td>Repeat what have been observed.</td>
<td>Try to summarize, analyze and structure, based on existing knowledge</td>
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<td><em>Strong, relatively fast, but limited to the learned solution.</em></td>
<td><em>Very weak.</em></td>
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<tr>
<td>By Education</td>
<td>Example cases eases learning of methods</td>
<td>Systematic approach to enrich knowledge and enhance level of skills</td>
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<tr>
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<td><em>Strong, fast.</em></td>
<td><em>Strong, fast.</em></td>
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Learning in the robotics domain
Purpose, levels, learning approaches, ….

- Task distribution
- Task sequencing
- Context policy
- Execution parameters
- Motoric skills
- Control/model parameters

- Process
- Task
- Cartesian Motion
- Joint motion

- Exploration
- Imitation
- Education

- Reinforcement learning
- Learning by demonstration
- Supervised learning
- Iterative learning control

- Stochastic methods
- Deep learning
- Model-based
- ….
Common Problems when Applying Machine Learning

Questions to be answered

- How to get the large amount of trials in a real-world scenario?
- How to deal with uncertainties during production?
- Do we have time for learning?
- Are we sure that it is the solution what we want to have?
- Are we sure that we can rely on the solution?
  - from safety perspective,
  - from quality perspective, or
  - from production reliability perspective.

Carefully define
- Purpose of learning
- Constraints
- Metrics
- Prior-knowledge
Our approach: Skills-based application programming
Where machine learning may help
Robot Assembly Skills

Re-usable robot functions that are intuitive for application engineers

SnapInsert (Start_Pose, Direction, \configParams)

- Approach start_pose
- Find right pose and alignment (Move with compliance)
- Move forward until snapped (Check resistant force, Optional corrective motion)
- Release & Move back

Grey-box
- Programmed by expert
- Hidden for standard application programming
- Guided calibration & configuration (automatic where possible)
- Accessible for experts

A higher-level robot function with application-oriented parameters usable via any user interfaces

Appropriate UIs for different user types may further increase ease-of-use

Machine learning may further reduce the efforts for parameterization/configuration
Example of (two-handed) snap insertion

Supporting arm

- Approach
- Hold-On
- Depart

Acting arm

- Approach
- Insert
- Check
- Release
- Depart

Flowchart:

- Start
- Approach
- Touched
- Approached
- Touched
- Found hole
- Push ended
- Check failed
- Check ok = Inserted
- Released
- End = completed

Error handling:

- Search
- Search failed
- Insert (begin)
- Insert (end)
- Check
- Release & Depart
Skill-based application programming

Select and parameterize skill functions

Objectives of UI design
- Reduce number of parameters for the user
- Hide/unhide lower-level parameters
- Multimodal & intuitive
Skills hierarchy and examples of skill parameters

Can the parameters be learned?

**Domain-specific skill**

- Snap
  - Start pose
  - End pose / condition
  - Search pattern
  - Search increment
  - Search region
  - Stop conditions
  - Direction
  - Force threshold

**Generic skills**

- Assemble phone
  - Align / Mate
  - Screw
  - Insert
  - Snap
  - Touch
  - Search Hole
  - Push
  - Release
  - Free Move
  - Move Compliant
  - Gripper control

- Desired path / direction
- Desired velocity
- Compliance setting
- Stop conditions
- Low-level control settings
Some experiments
Learning force threshold and starting pose for snapping
Some experiments
Learning force thresholds, start pose, and search policy for snapping

- Start
- Touch
- Push
- Pull
- Pattern, overlaid motion, ...
- Found hole
- Push ended
- Search
- Corrective motion?
- Search failed
- Check failed
- Check ok = Inserted

- Push only
- Ripple
- Align edge

- Force along X
- Force along Y
- Force along Z
- Torque around X
- Torque around Y
- Torque around Z
Recall: Skills-based application programming

Where machine learning may help

- Teach prior knowledge
- Grasp, align, insert, ...
- Use/select skills
- Use application knowledge
- Grasp Wheel 1, Insert Wheel 1, ...
- Learn/improve motoric skills
- Learn context policies
- Learn execution parameters
- Machine learning
- Machine learning
- Learn new skills

Current focus
Recall: Common Problems when Applying Machine Learning
Questions STILL to be answered

- How to get the large amount of trials in a real-world scenario?
- How to deal with uncertainties during production?
- Do we have time for learning?
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- Are we sure that we can rely on the solution?
  - from safety perspective,
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Now investigating:
How far combination of simulation and real-world learning can help without introducing huge additional effort of modeling / model acquisition
This topic has been discussed within the “Productive 4.0” project team at ABB Corporate Research. Many thanks to the project team members, especially Debora Clever, for the comments and discussions.

Productive 4.0 (https://productive40.eu/)
is a European co-funded innovation and lighthouse program, aiming at creating a user platform across value chains and industries, thus promoting the digital networking of manufacturing companies, production machines and products.