SARAFun
- Towards programming of assembly tasks by demonstration

Dr. Jonas Larsson
ABB Corporate Research, Sweden
Drivers & enablers for future industrial robotics

Disruptive technologies, market growth, & increase in R&D spending

<table>
<thead>
<tr>
<th>Technology Trends</th>
<th>Drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Digitalization</strong></td>
<td><strong>Market</strong></td>
</tr>
<tr>
<td>- Affordable large-scale computing power</td>
<td></td>
</tr>
<tr>
<td>- Higher-speed connectivity</td>
<td></td>
</tr>
<tr>
<td>- Cloud services</td>
<td></td>
</tr>
<tr>
<td>- Data-driven services</td>
<td></td>
</tr>
<tr>
<td><strong>Autonomy</strong></td>
<td><strong>R&amp;D Spending</strong></td>
</tr>
<tr>
<td>- Adaptivity / machine learning / AI</td>
<td></td>
</tr>
<tr>
<td>- Low-cost sensors / advanced sensors</td>
<td></td>
</tr>
<tr>
<td><strong>Human Integration</strong></td>
<td><strong>Customer needs</strong></td>
</tr>
<tr>
<td>- Ease of use, task-oriented instruction</td>
<td></td>
</tr>
<tr>
<td>- Human-robot collaboration</td>
<td></td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td><strong>Simplification</strong></td>
</tr>
<tr>
<td>- Open source, shared development</td>
<td></td>
</tr>
<tr>
<td>- Additive manufacturing</td>
<td></td>
</tr>
</tbody>
</table>

©ABB
March 26, 2018 | Slide 2
Robot programming – current and future

Classification of robot programming systems

Manual programming

- Graphical
- Task-level
- Robot-level
- Text
- Traditional solutions

Learning Systems

- Programming by Demonstration
- Autonomous Learning
- Long-term future solutions

Short-term future solutions
**Easy Robot Programming in Industry**

Simplification is more than a user-centred programming language

Robot Studio

Lead-through programming

Integrated
- hand
- in-hand vision
- force sensing

Integrated Part Feeding

Holistic approach to usability needed to achieve true Simplification

*(Hannover Messe 2015)*
Enable a non-expert user to integrate a new dual arm assembly task on a robot in less than a day with
• zero-programming robot instructions, multimodal robot interaction & force controlled dual arm assembly
• automatic grasp planning and finger design

**Platform**

**Start date:** 2015-03-01  
**End date:** 2018-02-28

Innovation Action under the Horizon 2020 ICT  
www.sarafun.eu

**Objective:** To develop a bi-manual robot system that will be capable to learn the assembly of two parts by human demonstration

**Objective:** To develop a bi-manual robot that enables teaching of assembly with advanced physical human-robot interaction

**Objective:** To develop an integrated planning framework to plan grasps and optimize the finger design for industrial grippers to facilitate the clamping and mating of parts

**Objective:** To develop strategies to improve and maintain grasp stability for industrial grippers

**Objective:** To validate SARAFun project results in real assembly scenarios
SARAFun – Integration process

Overall Workflow of Robot Integration

Phase 1: Task Definition, Teaching by Demonstration
- Define components
- Skill selection
- Track human hand and part
- Key-frame generation
- Assembly Constraints

Phase 2: Design Solution, Virtual Program and Finger Design
- Create nominal program
- Finger design and grasp selection
- Visualize complete robot program
- Generate robot fingers

Phase 3: Train Assembly Task, Learning by Doing
- Attempt each operation (pick, assemble, etc.)
- User can guide through assembly operation
- Corrective actions through PHRI
- Learning skill parameters

Production and Maintenance
- Run production
- Maintenance
- Provide user feedback
- Error recovery
SARAFun Consortium

| Participant No | Participant organisation name                                 | Country       |
|----------------|----------------------------------------------------------------|
| 1 (Coordinator)| ABB AB [ABB]                                                   | Sweden        |
| 2              | CENTRE FOR RESEARCH AND TECHNOLOGY HELLAS [CERTH]              | Greece        |
| 3              | KUNGLIGA TEKNISKA HOEGSKOLAN [KTH]                             | Sweden        |
| 4              | LUNDS UNIVERSITET [ULUND]                                     | Sweden        |
| 5              | UNIVERSITÄT BIELEFELD [UNIBI]                                  | Germany       |
| 6              | FUNDACION TECNALIA RESEARCH & INNOVATION [TECNALIA]            | Spain         |

**Expertise:** control, perception, cognition, sensor integration, human movement analysis

**Partner Tasks**

- CERTH - Assembly key frame extraction using visual feedback, pHRI control for teaching assembly with safety, automatic motion generation between key frames, assembly via deformation and insertion, teaching by demonstration using visual feedback and pHRI
- Bielefeld - grasp planning, integrating tactile sensors, learning to improve the robustness of grasping and to monitor grasp stability in an online fashion
- KTH - Controllers for bimanual folding assembly under uncertainties, Behavior trees to execute and monitor tasks
- ULUND - robotic force control and force estimation for use in assembly and contact operations in the SARAFun teaching and learning, as well as the knowledge base and task modeling
- Tecnalia - Human studies and monitoring of how humans perform assembly operations
Thank you!