Towards Human-Robot Cooperation – Systematic Approach and Applications within the Volkswagen Group

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Dr. T. Krüger, Dr. H. Heyn – R & D Robotics - Volkswagen AG
Towards Human-Robot Cooperation – Systematic Approach and Applications within the Volkswagen Group

1. Motivations
2. Applications within the Group
3. Systematic Approach for Car Assembly
4. Human-Robot Cooperation in Smart Factory Environments
5. Conclusion
Towards Human-Robot Cooperation – Systematic Approach and Applications within the Volkswagen Group

1. Motivations
Drivers of Innovation
Human-Robot Cooperation and New Robot Concepts (HRC)
Technology Push
Human-Robot Cooperation and New Robot Concepts (HRC)

- Algorithms and Machine Learning
- Sensors
- Robots – Mobile Platforms – Handling Technology
<table>
<thead>
<tr>
<th>Technology Push</th>
<th>Human-Robot Cooperation and New Robot Concepts (HRC)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Object Recognition for Bin Picking Tasks</strong></td>
<td><strong>Intuitive User Interfaces</strong></td>
</tr>
<tr>
<td>Robot-Integrated Sensors e.g. Force/Torque Sensors</td>
<td>Supplemental Sensors e.g. Capacitive Skins</td>
</tr>
<tr>
<td>Safe Robots and Control Systems</td>
<td>Lightweight Robots</td>
</tr>
</tbody>
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Drivers of Innovation
Human-Robot Cooperation and New Robot Concepts (HRC)
The Average Age of the Population is Increasing Worldwide

Median age of the population per region

- Europe
  - 45 years
  - ~ 40 years

- North America
  - ~ 40 years

- Asia
  - 34 years

- Africa
  - 30 years

Europe

Reference: Volkswagen AG

Germany 2013:
- median age men 44.5 years
- median age women 46.8 years

References:
2. German Federal Institute for Population Research
Increasing Average Age of Employees and Physical Stress

Average age in the Golf assembly in Wolfsburg

<table>
<thead>
<tr>
<th>Year</th>
<th>Average Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>38.9</td>
</tr>
<tr>
<td>2003</td>
<td>41.0</td>
</tr>
<tr>
<td>2008</td>
<td>42.2</td>
</tr>
<tr>
<td>2012</td>
<td>43.6</td>
</tr>
<tr>
<td>2018</td>
<td>45.0</td>
</tr>
</tbody>
</table>

Reversibility of physical impairments

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Percentage of Reversible</th>
<th>Percentage of Irreversible</th>
</tr>
</thead>
<tbody>
<tr>
<td>bis 24</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>25-34</td>
<td>96</td>
<td>4</td>
</tr>
<tr>
<td>35-44</td>
<td>37</td>
<td>63</td>
</tr>
<tr>
<td>45-54</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>55-64</td>
<td>31</td>
<td>69</td>
</tr>
</tbody>
</table>

Reference: Reinhart und Egbers, iwb Munich, 2011
Increasing Average Age of Employees in the Assembly and Consequences

Consequences:

• Increasing percentage of employees with physical impairments

• Differences in capabilities of employees

• Requirement for improved ergonomics and age-appropriate working environments

• Reduced flexibility in suitable work assignments for employees
Ergonomic Challenges are Being Answered with Multiple Measures

Reference:
Volkswagen AG

Reference:
Volkswagen AG

Reference:
VW Poznan

Reference:
Audi AG
Human-Robot Cooperation as New Approach between Manual Labour and Full Automation
Aspects Related to Personnel Management

„The lucky coincidence, that the baby boomer generation is entering retirement, makes it possible to reduce and automise ergonomically unfavourable workplaces without laying off employees.“

Dr. Horst Neumann,
Human Resources and Organization
Volkswagen Aktiengesellschaft

Reference: Die Welt, February 2015
Aspects Related to Personnel Management

- between 2015 and 2030 an extraordinarily high number of employees will enter retirement
- **Possibility to support or replace employees with intelligent robots**
- Still hire junior staff in in today‘s scale

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**Age distribution of the Volkswagen workforce**

In Germany 2014

Reference: Die Welt, February 2015
Motivations to Utilize Human-Robot Cooperation

- Ensuring Ergonomics
- Increasing Productivity
- Improving the Quality of Work
- Improving Precision
- Relaxing Cycle Time Adherence
- Enhancing Flexibility
- Mastering Complexity
- Assuring Process Quality

02.10.2015
IROS 2015 Hamburg - Dr. T. Krüger Volkswagen AG
Towards Human-Robot Cooperation – Systematic Approach and Applications within the Volkswagen Group

1. Motivations

2. Applications within the Group
Potential for New Robot Technologies in Assembly and Logistics

- > 44,000 robots globally in use at Volkswagen
- High level of automation already in car body construction
- Highest potential for HRC in assembly and logistics processes
Applications within the Volkswagen Group

Volkswagen Salzgitter

Audi Ingolstadt

Audi Ingolstadt

Volkswagen Sachsen

Audi Neckarsulm

...
Applications within the Volkswagen Group

**Volkswagen Sachsen**
Handling of actuators and sensors with Bosch „APAS“

Goals:
- Ergonomical support of the employee
- Relaxing cycle time adherence
- Improving quality

Project timeline:
- 5 months till safety approval (Berufsgenossenschaft)
- 6 months till SOP
Applications within the Volkswagen Group

Audi Ingolstadt
  Passing coolant expansion tank to employee with MRK-Systeme „KR5SI“

Goals:
  • Improved ergonomics and taking over tasks without added value
  • Employee defines the cycle time, not the robot

Reference: Audi AG
Applications within the Volkswagen Group

Volkswagen Salzgitter
Application of Universal Robots „UR 5“ in the motor assembly – different scenarios since 2013

Goal:
Ergonomical support of the employee, reducing monotony

Reference: Volkswagen AG
Applications within the Volkswagen Group

Audi Neckarsulm
Automated tailgate assembly using a safe industrial robot (employee not in the workspace at the same time)

Goal:
Acceptance testing for industrial robots in HRC settings

Project timeline:
~ 24 months until safety approval of test area

Reference: Audi AG
HRC Applications – Lessons Learned

- Reliable operation of HRC systems
- Robots are perceived as a support measure
- Important: The employee defines the cycle time, not the robot.
Towards Human-Robot Cooperation – Systematic Approach and Applications within the Volkswagen Group

1. Motivations
2. Applications within the Group
3. Systematic Approach for Car Assembly
Systematic Approach for the Field of Car Assembly

Work Content Analysis

1. Operations:
   - Part separation
   - Gripping, handling
   - Positioning, mounting

2. Frequency of particular tasks
Systematic Approach for the Field of Car Assembly

Work Content Analysis

Evaluating Potential for Automation

Criteria for Classification
- Accessibility
- Type of movement
- Tolerances
- Positioning support measures, etc.

Reference: dpa, Volkswagen AG
Systematic Approach for the Field of Car Assembly

- Work Content Analysis
- Evaluating Potential for Automation
- Ergonomical Classification

1. EAWS* method
   or
2. Criteria-based:
   - Overhead work
   - Car cabin
   - Body posture
   - Weights, etc.

Reference: Volkswagen AG

* Ergonomic Assessment Worksheet
Systematic Approach for the Field of Car Assembly

- Work Content Analysis
- Evaluating Potential for Automation
- Ergonomical Classification
- Evaluating the potential of work stations for the realization of HRC applications.
- Selection and Detailed Analysis
- Validation of Potentials and Efficiency
- Pilot Projects
- Development of Technical and Organizational Solutions
- Implementation into Series Production / Multiplication of the Solution
### Examples of Relevant Lightweight and HRC-Capable Robots

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>MRK-Systeme</th>
<th>Universal Robots</th>
<th>gomTec</th>
<th>Bosch</th>
<th>KUKA</th>
<th>FANUC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>KR5 SI</td>
<td>UR 3 / UR5 / UR10</td>
<td>Roberta</td>
<td>APAS</td>
<td>LBR iiwa</td>
<td>CR35iA</td>
</tr>
<tr>
<td>Payload</td>
<td>5 kg</td>
<td>3 kg / 5 kg / 10 kg</td>
<td>4 kg / 8 kg / 12 kg</td>
<td>1,5 kg</td>
<td>7 kg / 14 kg</td>
<td>35 kg</td>
</tr>
<tr>
<td>Conformity to standards certified</td>
<td>by Berufsgenossenschaft</td>
<td>Certificate from TÜV Nord *</td>
<td>Certificate from TÜV Nord * envisaged</td>
<td>by Berufsgenossenschaft</td>
<td>Approval for entire application</td>
<td>Certificate from TÜV Süd</td>
</tr>
</tbody>
</table>
| Advantages   | • Contact-free and tactile sensor skin  
• Padding  
• Proved industrial capability | • Easy operation  
• Established in the market, proved industrial capability | • Integrated gripper and camera system  
• Intuitive operation | • Integrated gripper  
• Contact-free and tactile sensor skin | • Sensitivity through integrated sensors  
• High flexibility (7-axis-kinematics)  
• Platform FlexFellow | • High payload |
| Serial Application within the group | **Audi Ingolstadt:** Passing of coolant expansion tanks and bin picking. | **VW Salzgitter:** Lubrifying bearing points, placing screws, mounting actuators | **VW Sachsen:** Mounting of sensors and actuators |

* TÜV NORD is not accredited for EN ISO 10218-1: 2011
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Vision of a Mobile Assembly Assistant
Requirements for the Automotive Production

- Learning, autonomous robots
- Agile through mobile platforms
Vision of a Mobile Assembly Assistant
Requirements for the Automotive Production

• Learning, autonomous robots
• Agile through mobile platforms
• Dynamic environment recognition
Vision of a Mobile Assembly Assistant
Requirements for the Automotive Production

- Learning, autonomous robots
- Agile through mobile platforms
- Dynamic environment recognition
- Flexible and safe gripping systems
Vision of a Mobile Assembly Assistant
Requirements for the Automotive Production

• Learning, autonomous robots
• Agile through mobile platforms
• Dynamic environment recognition
• Flexible and safe gripping systems
• Efficient vision systems
Vision of a Mobile Assembly Assistant
Requirements for the Automotive Production

• Learning, autonomous robots
• Agile through mobile platforms
• Dynamic environment recognition
• Flexible and safe gripping systems
• Efficient vision systems
• Modular, platform independent functionalities
• Interaction through voice and gesture control
• Intention recognition / collision avoidance
• Complete integration into existing plant architectures (simulation, „plug and produce“, etc.)
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- Enabling technologies have reached necessary maturity level
- Acceptance and availability can be observed
- Integration of multiple subsystems results in new, intelligent systems solutions
- Assembly and logistics offer high potentials for HRC and represent challenges as well
- New concepts and approaches for the planning of work stations necessary
Holistic Consideration when Planning Work Stations

HRC-System Competence

Tasks and Employee
- Ergonomics, Monotony, Individual Limitations, etc.

Robots and Automation Technology
- Technical Capabilities, Periphery, Safety Measures, etc.

Overall Design
- Work Station and Product
  - Workflow, Geometries, Risks, Industrial Safety, Standards, etc.