Demonstration of a Concept for Scalable Automation of Assembly Systems in a Learning Factory

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Agenda

1. Introduction
2. Literature review
3. Approach for the design of scalable assembly systems
4. Application of the approach to the Learning Factory Global Production at KIT
5. Summary and Outlook
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Introduction

Background and problem statement

Change drivers challenge companies operating assembly systems in global production networks

- Rising quality requirements
- Increasing labor costs
- High worker fluctuation

Need for a concept for the design of changeable assembly lines with scalable degrees of automation to face change drivers.

Sources: [1], [3]  
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Agenda

1 Introduction

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4 Application of the approach to the Learning Factory Global Production at KIT

5 Summary and Outlook
## Degrees of automation

### Literature review

### Degrees of automation

**Degree of automation**

\[
\text{Degree of automation} = \frac{\text{number of automated functions}}{\text{total number of all functions}}
\]

### Categories of automation

1. **Manual assembly systems**
2. **Partially automated assembly systems**
3. **Fully automated assembly systems**

### Modules of assembly stations

- **Transportation**
- **Feeding of parts**
- **Process itself**

### Sources:

[4], [5], [6], [7]
Key Performance Indicators (KPIs) for the evaluation of assembly systems

The degree of automation of assembly systems has an impact on economic efficiency that can be evaluated by KPIs.

Sources: [4], [8], [9], [10], [11], [12], [13], [15], [16], [17], [18], [19]
Adaptability of assembly systems in terms of flexibility and changeability

**Change enablers: Enablement of changeable assembly systems**

- Compatibility
- Universality
- Mobility
- Modularity
- Scalability

**Change drivers can be addressed by implementing change enablers which can be evaluated by a changeability potential analysis.**

Sources: [1], [2], [20]

Picture: Nyhuis, Reinhart & Abele (2008)
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Approach for the design of scalable assembly systems

Concept of scalable automation

The change enablers compatibility, universality and mobility are prerequisites for modularity, which in turn is necessary for scalability.

Changeability and automation

- Scalability as a change enabler
- Changeability of an assembly system is negatively correlated with the degree of automation due to interfaces of automated modules

<table>
<thead>
<tr>
<th>Compatibility</th>
<th>Universality</th>
<th>Mobility</th>
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<tbody>
<tr>
<td>Modularity</td>
<td></td>
<td></td>
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<tr>
<td>Scalability</td>
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Degree of automation:

1. Low
2. High
Approach for the design of scalable assembly systems

Technical potential for scalable automation and KPI analysis of different configurations

2³ = 8 different degrees of automation per assembly station

Identification of potential degrees of automation from both a technical as well as an economic perspective.

Technical perspective
- Difficulty of automating specific modules and automation of closely related modules
- Guaranteeing worker safety
- Consideration of space and organization
- Consideration of change enablers

Economic perspective
- Anticipation of impact of automation on KPIs and KPI requirements
- Analysis of the trade-off between investment costs and labor costs
- Decision about purchase or leasing
Agenda

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3. Proposed approach and model application
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Application of the approach to the Learning Factory

Learning Factory Global Production at KIT

Product: electric motor

Assembly system: Manual line configuration

Pressing Station 1
Pressing Station 2
Pressing Station 3
Pressing Station 4

Joining Station 1
Joining Station 2

Screwing Station 1
Screwing Station 2

Magnetizing Station

Testing Station
Application of the approach to the Learning Factory

Application of the approach using scenarios

**Scenario 1**
- Rising quality requirements
- Monitoring of the press capacity and the torque

**Scenario 2**
- Increasing labor costs
- Full automation of a pressing and a joining station

**Scenario 3**
- High worker fluctuation and further increasing labor costs
- Automation of the transportation of a screwing station
Application of the approach using scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Transportation</th>
<th>Process</th>
<th>Feeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>2</td>
<td>100%</td>
<td>100%</td>
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</tr>
<tr>
<td>3</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
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</tbody>
</table>

Degree of automation:

- **Starting situation:** 0%
- **Scenario 1:** 31%
- **Scenario 2:** 56%
- **Scenario 3:** 59%

The scenarios demonstrate how the degree of automation can be continuously adapted to change drivers.
Application of the approach to the Learning Factory

Didactic concept for the application of the approach

**Scenario 1**
- Analysis of change drivers
- Analysis of technical potential of the assembly line for scalable automation
- Net present value analysis for evaluating potential assembly line configurations
- Assembly in line with optimal configuration and ex-post performance assessment of KPIs

**Scenario 2**

**Scenario 3**

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**E-Learning Course:**
Theoretical background

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**On-site training in Learning Factory:**
- Analysis of change drivers
- Analysis of technical potential of the assembly line for scalable automation
- Net present value analysis for evaluating potential assembly line configurations
- Assembly in line with optimal configuration and ex-post performance assessment of KPIs
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**Summary and Outlook**

**Summary of approach and outlook on extension**

### Approach for technical implementation of scalable automation

Assembly line consisting of individual workstations with independent modules:

<table>
<thead>
<tr>
<th>Transportation</th>
<th>Feeding of parts</th>
<th>Process itself</th>
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<tbody>
<tr>
<td><img src="image1.png" alt="Transportation Diagram" /></td>
<td><img src="image2.png" alt="Feeding of parts Diagram" /></td>
<td><img src="image3.png" alt="Process itself Diagram" /></td>
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### Application of the approach to the Learning Factory Global Production based on three scenarios

<table>
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<tr>
<th>Starting Situation</th>
<th>Scenario 3</th>
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<tbody>
<tr>
<td><img src="image4.png" alt="Starting Situation Image" /></td>
<td><img src="image5.png" alt="Scenario 3 Image" /></td>
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**Concept will be further promoted by Industrie 4.0 solutions being demonstrated in the Learning Factory for students and practitioners.**
Thank you for your attention!
<table>
<thead>
<tr>
<th>Reference</th>
<th>Reference details</th>
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## Literature references in the paper and presentation

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<tr>
<th>References</th>
<th>Source</th>
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