Smart Work Design – Improving Ergonomics and Efficiency of Assembly Processes by Virtual Production Planning

Dr. Lars Fritzsche, imk automotive GmbH
@ Montagesysteme 2014, Bad Nauheim, 18.02.2014
## Agenda

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Cross-industry engineering services and consulting.

**Engineering**

- **Product Development**
  - Ronny Göpfert
  - Mechatronic Systems
  - Structural Components

- **Production Planning**
  - Carsten Otto
  - Assembly
  - Bodyshop
  - Logistics

- **Information Technology**
  - Dr. Jens Trepte
  - Software Development
  - Support and Service

- **Ergonomics**
  - Dr. Lars Fritzsche
  - Ergonomic Work Design
  - Qualification and Training

- **Technical Consulting**
  - Ingolf Grüßner
  - Production Strategies
  - Product and Production Optimization

**Consulting**

**Strategic Development**

- Dr. Wolfgang Leidholdt
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Motivation for Virtual Planning

Digital production planning tools facilitate human-centered work design.

Costs
- Chances for redesign are best in an early stage of development due to strongly increasing costs after product design freeze.

Efficiency
- Digital tools enable efficient testing of alternative planning and design scenarios without physical mock-ups and any risks for operators.

Understanding
- 3D visualization helps to create a common understanding and thereby supports collaboration between design, planning, production, safety, etc.

Availability
- Today, digital data is readily available in most companies’ PLM systems.
Motivation for Virtual Planning

“Lessons Learned” What parts and processes are critical in Productivity and Ergonomics?

Virtual Planning

Simulation tools for virtual production planning

Costs for redesign

Chance for redesign

Increase [%]

Corrective Measures

Dr. L. Fritzsche, February 2014

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Reminder: Ergonomics = Productivity

Study of 56 teams (623 persons) at Mercedes-Benz assembly line. (Fritzsche, 2010)

- Up to **20% less absenteeism days** in teams with low ergonomic strain
- Up to **40% less assembly errors** in teams with low ergonomic strain

![Graphs showing the comparison between lowest 25% and highest 25% of ergonomic strain in terms of days of sick leave and number of errors.](chart)
Humans in the “Digital Factory“

In the past, humans were merely “background actors“ in the digital factory.

Requirements for human simulations were NOT fulfilled:

- Realistic movements in 3D
- Human-machine interactions
- Reasonable effort for generating simulations
- Analysis of production time and ergonomics based on industry standards
Tools for Human Work Simulation

Motion Capturing in Virtual / Mixed Reality

Benefits:
- Recordings of realistic human motions in action
- Physical feedback, natural collision avoidance

Drawbacks:
- High effort for scenario preparation and alternation
- Individual data is not objective and reliable → results lack validity

Results from EU-Project “CyberManS”

Motion Capturing Suit

Head Mounted Display

Real and augmented objects

Optical tracking

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Human Simulations based on Standards

Concept Design

3D-Simulation
- 3D simulation of robots
- Feasibility and reachability
- Estimated tact time

Offline programming
- Verified 3D robot simulation
- Reachability analysis
- Exact tact time

Specific controller (MTM & EAWS)

3D-Simulation
- 3D simulation of human work
- Ergonomic risk estimation
- Estimated tact time

3D verification
- Verified 3D human simulation
- EAWS ergonomic analysis
- MTM time analysis

Production Planning and Optimization
ema₅ uses a standard process language and a library of predefined operations:

- get and place object
- use automatic tool
- ingress / egress car
- etc.

**Not:** step(s) forward → stand upright → bend → hand to object → pick → object to body → step(s) sideward → turn → step(s) forward → bend → object to target → release → hand back

**Instead:** take part from box and place into device (= object reference)
## The Task Library

The task library is continuously growing, integrating more predefined operations and movements.

### Object Handling
- **Pick object(s)**
- **Place object(s)**
- **Move object(s) to target**
- **Move object(s) to position**

### Object Handling (Extended)
- **Hand over object(s)**
- **Regrasp on object(s)**
- **Move object(s) on path**
- **Create link to object(s)**
- **Remove link to object(s)**

### Body Movements
- **Walk**
- **Kneel / squat / stoop**
- **Single step in default direction**
- **Single step to target**

### Body Movements (Extended)
- **Full step**
- **Turn**
- **Get into vehicle**
- **Get off vehicle**
- **Slide to target**
- **Sit down**
- **Stand up**

### Manual Activities
- **Press / activate**
- **Bolt down manually**
- **Wipe on surface**

### Tool Handling
- **Use hand tool**
- **Move tool on path**
- **Move hand to tool center point**

### Hand-Arm Movements
- **Grasp**
- **Move hand(s) on path**
- **Move hand(s) to target**
- **Move hand to default position**

### Head Movements
- **Look at object**
- **Check / read**

### Synchronization
- **Wait**

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- Process definition by drag-and-drop using predefined operation sequences, supplemented by the specification of task parameters (target location, etc.)
### Semi-automatic ergonomic evaluation based on standardized EAWS tool

(Ergonomic Assessment Worksheet V1.3.3 © IAD and AMI 2012)
### Analysis of value-added time, waiting, walk ways, workload balance, etc.

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<th>#</th>
<th>type</th>
<th>duration [s]</th>
<th>time relevant</th>
<th>informations</th>
<th>added value [%]</th>
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<td>1</td>
<td>wait</td>
<td>1.557</td>
<td></td>
<td></td>
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<tr>
<td>2</td>
<td>walk</td>
<td>0.628</td>
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<td>-&gt; overall walkpath [m]: 0.775</td>
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<td>3</td>
<td>pick object(s)</td>
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<tr>
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<td>walk</td>
<td>3.999</td>
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<td>-&gt; overall walkpath [m]: 4.127, load in right hand [kg]: 2.000</td>
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<tr>
<td>5</td>
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<td>3.602</td>
<td></td>
<td>-&gt; load in right hand [kg]: 2.000, hand move distance [m]: 0.696, object move distance [m]: 0.040, type of tool movement: automatic, cycles [#]: 1</td>
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<td>6</td>
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<td>100</td>
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Examples of Application

ema© may be used for various applications in different industries.

- Moving Assembly Line
- Welding
- Car Ingress / Egress
- Interior/Footwell Assembly
- Commissioning / Logistics
Examples of Application

ema₆ analysis of walkways with moving assembly line.
### ema® in Product Development Process

#### Concept Design
- **Concept Workshops**
  - Planning premises
  - Standard structure
  - eHPV targets
  - Investment targets

- **Product Workshops**
  - Product concept
  - Feasibility/Buildability
  - eHPV analysis
  - Time spread

#### Development & Production Planning
- **Process Workshops**
  - Product optimization
  - Line balancing
  - Layout design
  - Logistics

- **Production Trials**
  - Line balancing
  - Layout design
  - Logistics

- **Qualification**
  - Training of standard process

- **CIP-Workshop**
  - Process optimization
  - Productivity

#### Production Trials & Ramp-Up
- **Simulation of CIP-measures**
  - Layout
  - Walkways
  - F-time
  - Ergonomics

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**Ergonomic Milestones**

- **MS1**
  - Investigation of new concepts and technologies:
    - Feasibility
    - Estimated production time
    - Estimated ergonomics risks

- **MS2**
  - Verification / Detailing of the production process:
    - F-time planning
    - Line balancing
    - Layout design
    - Ergonomics assessment

- **MS3**
  - Qualification of new work procedure:
    - Training of standard work process using ema-simulation

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**ema® supports the Product Development Process from Concept until EOP!**
Durchgängiger Ergonomie-Prozess
- die richtigen Werkzeuge in jeder Prozess-Phase

Quelle: AUDI AG, Dr. Markus Becker, Leiter I.E. Planung
www.imk-automotive.de
Benefits for Customers

- Easy verification of planning results in 3D environment
- Quick alternation and testing of scenario options
- Uses MTM standards for time estimation
- Uses EAWS for ergonomic risk assessment (and possibly any other standard method like OWAS, etc.)
- Compatible with all common data formats (.cgr, .jt, .dae)

ema\f helped to avoid mistakes in planning and to reduce costs for redesign.
Customers from Industry, Science and Education.
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Conclusions

Designing efficient assembly systems by using virtual production planning.

- Virtual production planning saves costs for redesign and late correction.
- The complex human workforce needs to be considered proactively.
- ema® enables easy simulation that leads to objective results.

→ However, in many companies a change of culture is needed to respect and understand the requirements of (manual) assembly systems early in product development – digital human simulations may be the key!
Experts for designing ergonomic and efficient production processes.

- **Ergonomic risk assessment:**
  using standard methods (EAWS, LMM, etc.)

- **Proactive ergonomics:**
  ergonomic analysis and improvement of the design of products, processes, and equipment

- **Ergonomic optimization:**
  ergonomic analysis and improvement of work conditions in series production

- **Trainings in ergonomics:**
  customized trainings in basic knowledge, standard methods, and ergonomic behavior

- **Pilot applications of ema**
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