Towards a Factory-of-Things
Technologies for the factory of the future

Prof. Dr.-Ing. Detlef Zuehlke
Director Innovative Factory Systems IFS
German Research Center for Artificial Intelligence DFKI
Kaiserslautern/Germany

www.dfki.de/ifs
My background

Professor
Production Automation

German Research Center for Artificial Intelligence GmbH

Director
Innovative Factory Systems (IFS) and Center for Human-Machine-Interaction (ZMMI)

Chairman of the Executive Board

2 Co-Chairmen from Industry

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Outline

- Introduction
- The SmartFactory$^K_L$-Initiative
- R&D Projects
- Lessons learned
Our future world

Our life is deeply affected by many new technologies which have reached a sufficient level of maturity!

- WLAN, Bluetooth, UMTS...
- SmartPhones, PDA’s, SubNotebooks...
- Speech interaction, gesture control...
- From telephone to VoIP...
- The internet of things...

Information will be available anywhere, anytime, with any content, for any user using any device and any access
Complexity problem

Customer requirements

Planning

Complexity

Business processes

Operation

shorter lifecycles

global competition

in hardware requirements

in software logistics

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Challenges for future Production Systems

- Global & complex production structures
- Shorter PLC's
- More product variants
- Limited resources
- Global competition
- Need for continuous improvements in costs, quality and time
- Factor "Human"

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Outline

- Introduction
- The SmartFactory$^{KL}$-Initiative
- R&D Projects
- Lessons learned
Membership / Sponsorship *SmartFactoryKL*

- First multi vendor research, development and demonstration center for industrial ICT
- Goal: The integration of mature ICT into factory automation

Members:
- Rexroth
- Bosch Group
- Siemens
- BASF
- Phoenix Contact
- Wipotec
- Endress+Hauser
- Samson
- KEIPER
- DFK

Sponsors:
- Beckhoff
- Pfeiffer
- Grasslin
- Rittal
- MOBOTIX
- Weidmüller
- smartFactoryKL
Picture of the Shop Floor

continuous flow process
colored soap production

discrete handling process
bottling, handling, labeling, QC, packaging...

Live-Webcam:  http://www.smartfactory.de/webcam.de.htm
Outline

- Introduction
- The SmartFactoryKL Initiative
- R&D Projects
- Lessons learned
The wireless SmartFactory\textsuperscript{KL}

implemented technologies:
- supervisory communication > WLAN
- decentralized process control > RFID
- wireless device networks > ZigBee, Bluetooth
- failure messaging > GPRS
- localisation > UWB
## Wireless systems

<table>
<thead>
<tr>
<th>Technology</th>
<th>Quality of Service</th>
<th>Devices</th>
<th>Data Rates</th>
<th>Power Consumption</th>
<th>Roaming</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPRS/UMTS</td>
<td>High</td>
<td>Expensive</td>
<td>Slow</td>
<td>Slow response</td>
<td></td>
</tr>
<tr>
<td>DECT</td>
<td>Good</td>
<td>Few</td>
<td>Low</td>
<td>Low data rates</td>
<td></td>
</tr>
<tr>
<td>UWB</td>
<td>Low</td>
<td>Few</td>
<td>Low</td>
<td>Low data rates</td>
<td></td>
</tr>
<tr>
<td>WLAN</td>
<td>High data rates</td>
<td>&quot;everyone’s darling“</td>
<td>Fair</td>
<td>Unstable</td>
<td></td>
</tr>
<tr>
<td>Bluetooth</td>
<td>High quality</td>
<td>High</td>
<td>Low</td>
<td>High power</td>
<td>No roaming</td>
</tr>
<tr>
<td>Zigbee</td>
<td>High quality</td>
<td>To be developed</td>
<td>Low</td>
<td>Low data rates</td>
<td></td>
</tr>
</tbody>
</table>

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## Wireless application fields

<table>
<thead>
<tr>
<th>Class</th>
<th>Operation Type</th>
</tr>
</thead>
</table>
| Class A | Safety critical operation  
                    | Emergency stop, hazardous tasks                   |
| Class B | Time critical operation  
                    | Network control systems, predictable response time|
| Class C | Non critical operation  
                    | Nomadic information retrieval, „nice to have“ operation |

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Lessons learned

**Wireless**

*Pro’s*
- enabler for mobility
- brings flexibility
- may save installation cost

**But it...**
- should be complemented by wireless power supply
- needs intensive radio planning
- needs more frequency resources (on the long run)
- is vulnerable by environmental changes
- can not offer real-time transmission
- can be jammed easily and unnoticed

*Con’s*

Wireless systems do not yet meet basic industrial requirements!
They offer advantages in non-critical applications only!
**Project Group: „Digital Factory“**

**Objective**
- Demonstration of a „Digital Factory“

**Milestones**
- Setup of a digital model of the existing factory
- Simulation of the factory
- Automated control system generation
- Simulation support during operation
- Linking the ERP and MES Systems
- Creation of a research-, development- and demonstration platform

---

**Digital World**

- Siemens PLM Software
- SAP RESEARCH
- fiwa group
- Lucian Blaga University Sibiu/RO
- Federal Ministry of Education and Research

**Real World**

- OPC-Server
- Integrating the existing factory and the digital model
Project Group: „Digital Factory“

Planning

Simulation

Control

(Factory CAD, Solid Edge, NX)

(Plant Simulation, Process Simulate)

(Factory Link)

Backbone

OPC

WinCC Projects, Operator Panels

PLC Code

Analysis, Dynamic 3D Vis

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Lessons learned

**Digital factory**

**Pro’s**
- will reduce planning effort
- will reduce time to market
- allows for component re-use
- may save cost (on the long run)

**But it...**
- needs a collaborative platform
- needs intensive expertise by the users
- must be linked to the control level
- is for big players only

**Con’s**

A digital factory tool world will make planning and operation more effective!
But it needs years to develop and new standards to ease integration!
Smartphones as universal interaction devices

- Development of a platform-independent software for mobile phones of different manufacturers
- Data link via Bluetooth
- Automatic detection of available field devices
- Communication via heterogeneous infrastructure with different access paths and gateways

Result:
- 20 smartphones Java2ME: > 4 were o.k.
- > 6 had minor problems
- > 10 failed completely
Future interaction with smart production items

**SmartFactoryKL as a testbed:**
- 20 field devices can be controlled wirelessly via Bluetooth
- users can access them according to their tasks, education and preferences
- dedicated remote operation device is under development

- Dosing pumps
- Mass-flow meters
- Valves
- Weighing machines
- FlowUnit components
- Agitators

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Universal Interaction Device by UniPO GmbH

The first industrial product...

Universal Gateway

ISO-OSI

MCAP Layer

Transmission-Hardware

UART

Command-Handler

MCAP RFComm Layer

Transmission-Hardware

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The future challenge of designing user interfaces

Tomorrow...

Task:
Designing a good user interface

- Nomadic access
- Changing hardware
- Multiple dialogues
- Complex functions
- Fuzzy locations
- Lifetime 1 yrs.

Yesterday...

- Local access
- Known hardware
- Fixed dialogue
- Limited functions
- Known location
- Lifetime 20 yrs.

Solution:
Abstract description
Model-based
Run-time adaption
Different layers of UI abstraction

- Use model (useML)
- Analysis data (useDDL)
- Use model (useML)
- Abstract user interface
- Final user interface (source code)

Involved groups:
- Developer
- User
- Service
- ... analysis methods

- Data pool
- Qualitative data
- Quantitative data
- Structures
- Use data

- Structured database

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Lessons learned

**User-friendly operation**

- supports the user to do it right
- brings more flexibility
- is important for customer satisfaction

**Pro’s**

- must be developed with methodology
- must focus on the users tasks
- should be hardware independant
- should care for cultural differences
- should be treated as important as hard- and software

**But it...**

**Con’s**

Help the users to perform the tasks by a good usability!
Be prepared for rapid hardware changes and nomadic access!

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Location Based Services in Industrial Applications

- components
- logistics
- products
- control room
- location
- context
- people
- location and context based services
- context model
- location model
- task model
- service model
- XXX model

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Indoor Positioning Systems installed in the SmartFactoryKL

- Ubisense UWB-Realtime Positioning System
- RFID Grid for Mobile Workshop Navigation
- Cricket Ultrasonic Indoor Location System

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# Location Based Services in Industrial Applications

## World level
- **Accuracy:** 5-15m
- **3 axes**
- **Systems:**
  - GPS (US)
  - GLONASS (russ.)
  - GALILEO (europ. from '12)
  - cell phone localization

## Building level
- **Accuracy:** 0.5 – 1.5m / 3 - 5°
- **4 axes**
- **Systems:**
  - UbiSense
  - DOLPHIN
  - Cricket
  - WLAN localization

## Room level
- **Accuracy:** 1 – 10cm / 1.0°
- **4 - 5 axes**
- **Systems:**
  - iGPS-Laser
  - UbiSense
  - UWB localization

## Device level
- **Accuracy:** 1 – 5mm / 0.1°
- **5 – 6 axes**
- **Systems:**
  - ???
Lessons learned

Location-based services

**Pro’s**
- will be essential in wireless applications
- enable context and position dependancy
- enable a more efficient use of resources

**But it…**
- we need indoor location sensing systems
- we need location standards
- needs a careful handling of sensitive information (privacy)

We still need a convincing „Indoor-GPS“!
We should seriously discuss the very sensitive privacy issues!
The biggest challenge

design, setup and maintenance of highly complex systems must be improved in terms of

• Time
• Quality
• Cost and
• Complexity

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Advances on the device level

- **analog** (4-20mA)
- **digital** (Profibus)
- **smart + wireless** (WLAN)

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Device Modelling

Physical Device → Device Model

Energy-Model
- energy consumption
- power per mode

Service-Model
- elementary services
- working logic

Communication-Model
- layer
- protocol

Product-Data
- part number
- part description

CAD-Data
- mech. data
- electr. data

BPEL
XPDL
GSD
EDDL
STEP
PDB
STEP
IGES
Advances in Factory/Process Modelling

Enterprise

Site

Area

Business processes

Production processes

Process Cell

Process Unit

Equipment Module

Control Module

Batch processes

Production Line

Work Cell

Device

Controller

Discrete processes

Logistic processes

IEC62264
ISA95 1-5

UML models

IEC61512
ISA88 1-4

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Production in the 80th: *Electrical Signals*

Initial situation:
- Automation via electrical signals
Production in the 90th: *Bits and Bytes*

Main changes:
- Microprocessor technology
- Advances in digital signal processing

Driven by:
- Increasing functionality of the field devices
- High wiring effort
- High error rate during wiring of complex systems
Main changes:
• Mechanical and control modularity
• Increasing IT deployment in production

Driven by:
• Demand for faster design and faster setup of the equipment

Production in the 00th: *Functions*
Production in the 10th: Services

Main changes:
- Standardization of communication interfaces
- Orchestration via services instead of functions

Driven by:
- Integration of business and production systems

Service repository UDDI

Service providers

abstract mechatronic objects

Service + location

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Production in the 20th: **Semantics**

Driven by:
- The Internet-of-Things

MES → Business Logic based on Semantics

Semantic services + context
The Pyramid of Automation

yesterday

ERP-Level
Enterprise Resource Planning

MES-Level
Manufacturing Execution System

Control-Level
Machine controllers

Device-Level
Sensor-Actor-Machine

data sets

words

bytes

bits

WLAN

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The Pyramid of Automation today

ERP-Level
Enterprise Resource Planning
IP 183.77.19.0

MES-Level
Manufacturing Execution System
IP 183.77.xx.x

Control-Level
Machine controllers

Device-Level
Sensor-Actor-Machine

To services
Via functions
Via data
From signals

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The Pyramid Network of Automation Services tomorrow

from services
to services

Service repository UDDI

global services domain services

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Project: SoA-Architecture for the SmartFactoryKL

- Structure ISA95 B2MML
- Process BPEL
- Webservices WSDL
- Service repository UDDI
- Process deployment PDD
- Orders
  - BPEL-Engine
  - Java-invoker
  - HTTPS-Server
  - ACPLT/KS-Server
  - SIEMENS-PCS7
  - S7 PLC's
- ACPLT/KS-Client
- Field devices
  - sensors
  - actors

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A successful implementation of SoA requires the company-wide definition of tasks and services **first**!!

Tools and software come **second**!!
The next step: Semantic Services in the SmartFactory KL

- Product and process knowledge
  - Consumes services
  - Screening of matching services
  - Abfüllen process
    - RFID lesen
    - Ventil 1 öffnen
    - Ventil 2 öffnen
    - Ventil 3 öffnen
    - Pumpe 1 abfüllen
    - Pumpe 2 abfüllen
    - Pumpe 3 abfüllen
- Service model
- Component and plant knowledge
  - Offers services
  - Semantic discovery
  - Semi-automatic orchestration
Why semantics in industrial production?

- Can the product still be manufactured?
- Can another manufacturing station be passed first?

- Cognitive factory behavior
- Complexity control
- Flexibility and adaptability

Knowledge services context
Different Forms of Knowledge Representation

glossary

taxonomy

thesaurus

ontology
Interpretation of Context Data

The diagram illustrates the integration of various devices and sensors (listed as location) with a Reasoner and API, to provide an Interpretation Service. The usage of these services is shown to forward towards mobile devices, indicating a seamless flow of data and information in the context of smart factory operations.

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Usage Scenarios and Prototypes in the SmartFactory\textsuperscript{KL}

- **Mobile Maintenance**
  Derivation of the current situation of a maintenance worker using a mobile navigation device based on location information

- **Universal Interaction** (Touch And Connect)
  Which communication interface is suited for a special field device and guarantees a certain response time?

- **Reconfiguration of plants** (digital factory)
  Is this plant suited to manufacture a certain product?
Why Semantic Service Description?

- Repository (UDDI)
- WSDL
- OWL-S / WSDL-S
- BPEL

Syntactic: 
- WSDL
- OWL-S / WSDL-S
- BPEL

Semantic: 
- OWL-S / WSDL-S

Gap: 
- OWL-S / WSDL-S
Lessons learned

**SoA architectures**

- will decouple hardware from control engineering
- will bring more agility
- will focus on a semantic control level

**But it...**

- may have an unpredictable behaviour
- needs new expertise of users
- needs smart webservers in each device
- needs well defined service standards
- revolutionizes control engineering

**Pro’s**

**Con’s**

SoA is an enabler for the Factory-of-Things!
SoA is a new engineering paradigm and needs a different way of thinking!
Outline

- Introduction
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Key changes in the factory of the future

Everything is described by semantic services.

The factory of things:
- Everything is mobile.
- Everything is networked.
- Virtuality merges with reality.

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Requirements and challenges

Market Requirements
- higher agility
- higher mobility
- shorter product lifecycles
- improved quality

Enabling Technologies
- Wireless networks
- Low-power electronics
- Simulation
- Authentication
- Plug ´n play
- Smart devices
- SoA
- Location sensing
- Semantic web

Solutions
- digital factories
- worker mobility
- fast product changes
- network production

Challenges
- Complexity
- Education
- Training
- Safety
- Security
- Standardization
- Health risks
- Privacy concerns
- Definition of work
- Quality of service

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We need new engineering paradigms

From

the 80’s

Electrical engineering

Designing transistors, gates and circuits

Software engineering

Writing code

IF $B5 EQ #0A
THEN GOTO...

Mechanical engineering

Drawings

Placing buttons, switches and windows

Useware engineering

Modeling interaction objects and systems

Modeling mechatronic objects and systems

UML

Modeling objects and systems

VHDL

Modeling functions and systems

ARCHITECTURE xx67 OF nor_gate IS BEGIN y <= a NOR b; END xx67;

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Towards Future Production

- "Internet of Things"
- Global Production Systems
- Computer-integrated Manufacturing
- Fordism & Taylorism
- Mass Production

Productivity vs. Time

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Paradigms of the Factory of Things

- Highly Reconfigurable Processes
- Transparent and integrated Processes
- Context-sensitive Assistance

- Explicit Process and Product Description
  By means of Semantics

- Global, standardised Communication Architecture
  by means of SOA

- Structural Flexibility
  by means of Modularity

Increase of Productivity
Optimization of Process Quality
Efficient Use of Resources
Thank you!

shaping the future of manufacturing ICT