ENABLING PERSONALISED PRODUCTION WITH INTELLIGENT MANUFACTURING ENVIRONMENTS

GIL GONÇALVES, UNIVERSITY OF PORTO, PORTUGAL
SYSTEC

SYSTEC is a research unit hosted at FEUP and ISR and promotes: (i) academic excellence, (ii) worldwide networking with institutions and researchers with opportune scientific affinities to ensure the critical mass, (iii) interaction with end-users and stakeholders to promote the tuning with challenge-driven innovation dynamics, and (iv) integration with advanced formation activities.

SYSTEC addresses real world challenges by articulating theoretical and applied research in 4 Thematic Lines:

**SYSTEC–CONTROL**: Systems, Control, Optimization, and Estimation Technologies

**SYSTEC-NET**: Networked Robotic Vehicles and Systems Technologies

**SYSTEC-ENERGY**: Smart Energy Systems and Technologies

**SYSTEC-MANUFACTURING**: Smart components for Advanced Manufacturing Systems and Technologies
Design, implement and validate smart components for advanced manufacturing system aiming to introduce intelligence into industrial processes and contribute to the emergence of the intelligent manufacturing environments of the future, by implementing novel approaches into Cyber-Physical Production Systems.
Motivation

FROM CRAFT PRODUCTION TO PERSONALISED PRODUCTION
From craft production to personalised production

**TRENDS**

**Customer specific production:**
- Individualised products
- Mass production but individual design
- Small lot sizes, one piece flow

**Sustainability:**
- High efficiency and near-to-zero emission
- Reusability of machines and equipment
- Avoid waste

**Digitisation and networking:**
- Digital & virtual factory
- Integrated value chains
- Constant change
Industry 4.0

Technology:
- Digital networking production facilities
- Fast pace of technological change and innovative technologies

Customers:
- Customised solutions
- Wide diversity of customers and markets
- New services

People:
- Demographic development
- Training and qualifications
- Interaction between human beings and technology
What’s so different about industry 4.0?

► It’s not about replacing the existing assets
► It’s about mastering disruptive technologies along three dimensions:
1. Operational effectiveness
2. New business models
3. Digital transformation of the company

Replacement of equipment

100 Replacement of complete lines necessary
~ 10 - 20 Little replacement, as tooling equipment could be kept, only conveyor belt needed
~ 80 - 90 High level of replacement as tooling equipment was replaced by machines
~ 40 - 50 Existing machines are connected, only partial replacement of equipment

SOURCE: Statistisches Bundesamt, Deutsche Bundesbank; Prognos; Thomas Nipperdey; McKinsey
Towards Personalised Production
INTELLIGENT MANUFACTURING ENVIRONMENTS
Digitisation and networking

► Vertical integration of hierarchical subsystems leads to smarter factories
► Supports horizontal integration through value networks
► End-to-end digital integration of engineering.
► Based on this global collaboration network, the consumers, design activities, manufacturing, and logistics can interact above the cloud
Small lot sizes, one piece flow

- Equipment can be reconfigured automatically to produce multiple types of products
- New products can be directly ordered to the system, helping to cope with ever changing market and discerning consumption demands
- The self-organization and dynamic reconfiguration allows new machines to join the system in a plug ‘n’ produce fashion
- Malfunction machines will not affect the system due to the machine redundancy
Customer specific production

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** Intelligent Manufacturing Environments **

**plug ‘n’ produce**

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Fault tolerant

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Sustainability

- Big data analytics, we can establish an accurate knowledge of production process and guarantee systems with a stable product quality and volume of finished products.
- Needed raw materials can be determined before production and product redundancy can be minimized.
- Equipment operate in more intelligent way, hence, the energy consumption can be optimized and reduced.
Avoid waste

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High efficiency and near-to-zero emission

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Advanced Manufacturing Systems can produce small-lot products efficiently

Setup time is minimized when switching between different types of products

Production process is optimized with the help of big data

Average manufacturing routes are shrunk

Utilization rate of machines and other resources is improved

“Any customer can have a car painted any color that he wants so long as it is black.”

Henry Ford
Enablers

R&D EFFORTS IN INTELLIGENT MANUFACTURING ENVIRONMENTS
Enablers of Personalise Production

- **I-RAMP³**
  - Intelligent Network Devices for fast Ramp-up

- **SelSus**
  - MANUFACTURING SYSTEMS

- **eBorn**
  - Innovative Reuse

**RAMP-UP**
- Intelligent Network Devices for fast Ramp-up

**PRODUCTIVITY**
- Health Monitoring and Life-Long Capability Management

**REUSE**
- Reuse of modular knowledge Based devices and technologies
There are five essential characteristics to a Smart Component:

- Reconfigurable and modular - must be capable of extend its capabilities by adding new software modules and it must be capable of reconfigure it’s internal operation in runtime.

- Data processing - system state assessment, event detection and fault alarm requires data processing capabilities.

- Communication and interface capabilities - capable to talk with lower level devices (sensors and machines), same level (other Smart Components) and higher level (cloud servers, MES).

- Process events and act - certain degree of smartness and autonomy; in case any event of interest, the system must be capable of detecting it and take the proper actions.

- Real-time data acquisition, processing and delivering - devices operate at variable (real)time scales, performing multiple tasks in a coordination.
Smart Component Servo press

Ramp-up scenario:
Ramp-up after component/product exchange

Derived use-cases
#1 Servo press auto-configuration with recipe database
#2 Plug & produce sub-component exchange for fast re-configuration
#3 Automated rapid high-precision parameter finding and optimization for pressing job
#4 Drag & drop visualization authoring and fast integration of equipment and sensor data

Application areas:
High precision joining & pressing processes  High-precision pick & place tasks

Functionalities:
• Auto-detection of equipment, tasks, parameters Self-describing capabilities
• Parameter finding and optimization
• Connection with visualization elements via drag & drop
Overall architecture
Smart Component Cloud

Cyber-Physical representation

Inter-process communication

Advanced data processing
Dynamic modularity

Smart Component

Dynamic Modular Software Reconfiguration (cloud)

- PiezoElectric
- Voltage
- Flow

Network Level

Data Treatment Level

Sensor Level

Control Chart

Normalization
Equipment awareness

With Smart Components equipment is capable of recording process data which can be analyzed and statistical information can be deduced.

Machine builders

- Instead of recycling an old machine or its components, machine builders evaluate the wear of old machine/components (with built-in software), modify it and re-use for new purposes. Evaluation takes a few minutes. **Saving of money can reach up to 50%.**

Plant owners

- Keeping brand-new components in stock is no more necessary. Components are chosen according to the needs. **Stock cost saving can reach 50%.**

New business model

- Equipment/components bought/sold through new modern e-commerce services such as market places. This enables new business opportunities for all partners.
Production line construction and optimization

- With smart components, old equipment can be optimally used for dedicated purposes. Advantages:
  1. Money for experts and new equipment’s can be saved (~ 50% of price per equipment).
  2. Line construction time can be reduced by ~ factor of 2 (all information is available within minutes).

Degradation monitoring during the production

- Live monitoring of wear of components is possible. This allows to prevent failures and optimize maintenance, both lead to save of expenses. Generation of use/ware information.

Owner/Vendor sells smart component

- **Without smart component**: Owner has to remove equipment from production, store it, evaluate its price, contact Vendor, negotiate about price, wait for buyer.
- **With smart component**: Owner generates LCSID files and sends these files to market place (< 1min). Waits for a buyer without stopping the production. Gain of time/effort, and money can be drastically increased. This is new business model.
Line update (demonstrator)
System level

Tools for planning and assessment

**Functionalities:**
- Generic planning and assessment software tool
- Extensible workbench architecture
- Requirements tool
- Solution generator
- System assessment tool
- Layout planner
- Market place for re-used equipment
- Integrated software suite for planning and decision support
Personalised Production

INTELLIGENT MANUFACTURING ENVIRONMENTS
Intelligent Manufacturing Environment ecosystems

Smart Phone

Applications
- Platform / Operating System
- Sensors / Connection with physical world

Smart Factory

Applications
- Platform / Operating System
- Sensors / Connection with physical world
Intelligent manufacturing environments & human

1st industrial revolution
- Work mechanization

2nd industrial revolution
- Assembly line

3rd industrial revolution
- Automation

4th industrial revolution
- Operator?
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Gil Gonçalves, University of Porto, Portugal

gil.goncalves@fe.up.pt

Q&A

- Security and dependability in the automatic update of applications and configuration parameters.

- Reconfigurability (and flexibility) in the logical layer (software and control); physical layer is not addressed.

- Quality assurance is executed at the machine level and quality information shared with other systems (e.g. Quality Management System for certification and compliance).

- Extent to which data analytics is being used in the different levels (smart components and smart components cloud).

- Level of complexity of the artificial systems and the capability to interact with the operators.

- Capacity of the humans to understand the automatic methods used for reconfiguration (system and machine level).

- What will be the driver for the 5th industrial revolution?