Trasformazione digitale per una fabbrica 4.0 uomo-centrica

Treviso | Giovedì 23 novembre 2017
Open Seminar: Industrial internet-of-things (IoT) and supply chain integration

Modellazione e controllo di sistema applicati ai processi manifatturieri

Alessandro Beghi
Professore Ordinario di Automazione, Dipartimento di Ingegneria dell’Informazione
Università degli Studi di Padova
Where are we going? Industry 4.0

- Industry 4.0 is a collective term for technologies and concepts of value chain organization
- Based on the technological concepts of Cyber-Physical Systems, the Internet of Things and the Internet of Services
- It facilitates the vision of the Smart Factory
- Vision:
  - Within the modular structured Smart Factories, cyber-physical systems monitor physical processes, create a virtual copy of the physical world and make decentralized decisions
  - Over the Internet of Things, Cyber-physical systems communicate and cooperate with each other and humans in real time
  - Via the Internet of Services, both internal and cross-organizational services are offered and utilized by participants of the value chain
Implementing Industry 4.0 scenarios

- **Interoperability**: the ability of cyber-physical systems (i.e. workpiece carriers, assembly stations and products), humans and Smart Factories to connect and communicate with each other via the Internet of Things and the Internet of Services.

- **Virtualization**: a virtual copy of the Smart Factory which is created by linking sensor data (from monitoring physical processes) with virtual plant models and simulation models.

- **Decentralization**: the ability of cyber-physical systems within Smart Factories to make decisions on their own.

- **Real-Time Capability**: the capability to collect and analyse data and provide the derived insights immediately.

- **Service Orientation**: offering of services (of cyber-physical systems, humans or Smart Factories) via the Internet of Services.

- **Modularity**: flexible adaptation of Smart Factories to changing requirements by replacing or expanding individual modules.
Driving the transition

- **The main drives:**
  - Strong customization of products under the conditions of high flexibilized (mass-) production
  - Enhanced automation technology by introducing methods of self-optimization & self-configuration
  - Self-diagnosis, cognition and intelligent support of workers in their increasingly complex work

- **Cost-effective manufacturing:**
  - Make the best use of various data sources providing worthwhile information about different aspects of the process/product/value chain
  - Today: utilization of data for understanding the current condition and detecting faults and failures
  - Tomorrow: components and systems able to gain self-awareness and self-predictiveness
“Information-fueled” modeling and control

- Processes and products are enriched by the availability of (large amount of) data
- Data are used to build **models** (to describe, analyze, design, predict …)
- Widespread adoption of data-driven approaches
- Toward the digital twin:
  - Virtual prototyping
  - Rapid prototyping
  - Closing the loop between design and operation
  - Adaptivity & reconfiguration, repeated optimization
  - Systematic handling of the human-in-the-loop
- Paradigmatic examples:
  - Advanced Process Control
  - Optimization-based control
  - Virtual Prototyping for control design
Optimal equipment operation

- ICT sector
  - DCs are growing
  - Energy-intensive DCs

- DCs Energy Consumption
  - IT devices
  - UDP, UPS
  - CRAC

- Energy Efficient CRAC
  - new technologies
  - advanced control systems
Optimal equipment operation
Optimal equipment operation
Optimal equipment operation

Hierarchical Control

High-level

Objective & Constraints

Optimizer

Model

Setpoint

Local Controller

Plant/Process

Output

Low-level
Optimal equipment operation
Optimal equipment operation

Optimization Problem:
\[
\text{arg min} \quad \text{Input Power}
\]

- process air \([m^3h^{-1}]\)
- supply water \([lh^{-1}]\)

subject to
- CRAC model
- PC/Rm temperature \([°C]\)

Particle Swarm Optimization

\[
\begin{align*}
v_j(t + 1) &= w v_j(t) + c_1 R_1(t) [P_j(t) - x_j(t)] + c_2 R_2(t) \\
& \quad \cdot [P_g(t) - x_j(t)] \\
x_j(t + 1) &= x_j(t) + v_j(t + 1)
\end{align*}
\]

PSO: position, velocity

barrier function
Optimal equipment operation

Example: Thermal Load = 75 kW, \ External Air Temperature = 25 °C