Enrolling towards Industry 4.0

Panel Session Intelli 2017
Moderator: Leo van Moergestel
Panelists

- Gil Gonçalves, Faculdade de Engenharia da Universidade do Porto (FEUP), Portugal
- Sungshin Kim, Pusan National University, Republic of Korea
- Heinz Woern, Karlsruhe Institute of Technology (KIT), Germany
Presentations

- Gil Gonçalves: “Will robotics and artificial systems completely replaced the human operator in production?”
- Sungshin Kim: “Multivariate statistical techniques for fault detection and diagnosis of large-scale industrial processes.”
- Heinz Woern: "Intelligent robots for Intelligent Manufacturing-Industrie 4.0"
Panel session

- Three presentations
- Discussion, questions ...
WILL ROBOTICS AND ARTIFICIAL SYSTEMS COMPLETELY REPLACE THE HUMAN IN THE PRODUCTION ENVIRONMENT?

GIL GONÇALVES, UNIVERSITY OF PORTO, PORTUGAL
From craft production to personalised production

Companies are subject to constant changes in their operational environment (new regulations, economic up/downturns, environmental issues, technological innovation, competition and customer trends)

**Challenges for Industry**

- More demanding specifications
- Small lots and one-of-a-kind
- Material re-use and zero-waste
- Quality/performance after ramp-up
- Huge amounts of data
### Industry 4.0

<table>
<thead>
<tr>
<th>Era</th>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>1784</td>
<td>Based on mechanical production equipment driven by water and steam power.</td>
</tr>
<tr>
<td>2.0</td>
<td>1870</td>
<td>Based on mass production enabled by the division of labor and the use of electrical energy.</td>
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<tr>
<td>3.0</td>
<td>1969</td>
<td>Based on the use of electronics and IT to further automate production.</td>
</tr>
<tr>
<td>4.0</td>
<td>tomorrow</td>
<td>Based on the use of cyber-physical systems.</td>
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#### 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
Intelligent Manufacturing Environments

Virtual emulation: this will enable automatic start-up and reconfiguration.

Plug and produce components: facilitate the exchange of defective production units and the reuse of individual units for new products.

"I am finished."

Condition Monitoring: the filter reports a contamination level of 95%.

"I continue on to station 2."
What role for the human in these new intelligent manufacturing environments?

Mechanisation: steam and water machines mechanised some of the work

Assembly line: along with electricity brought mass production

Automation: robots and machines started to replace human workers on the assembly lines

CPPS: brings robotics and automation connected in an entirely new way and artificial systems that can learn, control and cooperate with each other.
WILL ROBOTICS AND ARTIFICIAL SYSTEMS COMPLETELY REPLACE THE HUMAN IN THE PRODUCTION ENVIRONMENT?

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Multivariate Statistical Techniques for Fault Detection and Diagnosis of Large-Scale Industrial Processes

July 24, 2017

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Contents
I. Introduction
II. Description of target system (Thermal power plants)
III. AAKR (Auto-associative kernel regression)
IV. Experimental results
Enrolling Towards Industry 4.0: Large-scale industrial processes

Solutions

- Process knowledge
- Data-driven approaches
- Fault Detection & Diagnosis
- Failure Prognosis
- Forecasting & Optimization
- Material balance
- Energy balance
- Experience
- Physical knowledge

Large-scale industrial processes

- [Power plant]
- [Aircraft engine]
- [Solar & Wind]
- [Manufacturing]
- [Railroad]
- [Chemical]

Objectives

- Performance improvement
- Failure prevention
- Maintenance scheduling
◆ Research background: Thermal power plants
  ▪ Main equipment in thermal power plants (TPPs) (Right)
  ▪ Statistics related with reliability of power plants (in South Korea) (Middle)
  ▪ Implementation of distributed control systems (DCSs) in TPPs (Left)

**Very dangerous conditions**
- Rotation speed: 3600rpm
- Steam temperature: 538°C
- Steam pressure: 169.8kg/cm²
- Voltage: 20kV

**Gradually increasing**
- “The number of unplanned shutdowns per year”
- Source: Korea Power Exchange (KPX) (2016)

![Graph showing the number of unplanned shutdowns per year from 2006 to 2015. The number of shutdowns increases over the years.]

**Massive historical operation data**
- “Ratio of worn-out facilities”
- Source: Korea Electric Engineers Association (2013)

![Graph showing the ratio of worn-out facilities from 2013 to 2018. The ratio increases significantly over the years.]

Source of video: https://www.youtube.com/watch?v=IdPTuwKEfmA
Multivariate statistical techniques: AAKR

- Non-parametric multivariate technique to estimate new query vectors by online local modeling
- Involves storing training data in memory and finding the relevant data in the database to answer a current query

**Similarity measure** (Distance function)

\[ D = \{x^1, x^2, \ldots, x^n\} \]

\[ x(k) = \begin{bmatrix} x_{\text{temp.}}(k) \\ x_{\text{press.}}(k) \\ \vdots \\ x_{\text{flow}}(k) \end{bmatrix} \in \mathbb{R}^m \]

\[ d^i(x^i, x(k)), \quad i = 1, \ldots, n \]

\[ K_h(d^i) = \frac{1}{\sqrt{2\pi h^2}} \exp \left[ -\frac{(d^i)^2}{2h^2} \right], \quad i = 1, \ldots, n \]

\( h \): bandwidth

**Weight assignment** (Weighting function)

\[ \hat{x}(k) = \frac{\sum_{i=1}^n K_h(d^i) \cdot x^i}{\sum_{i=1}^n K_h(d^i)} \]

\(<\text{Estimated vector}>\)

\[ e(k) = x(k) - \hat{x}(k) \]

\(<\text{Residual vector}>\)

\[ SPE(k) = e(k)^T e(k) \]

\(<\text{Test statistic}>\)

**Decision**

<table>
<thead>
<tr>
<th>Actual state</th>
<th>Decision</th>
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</thead>
<tbody>
<tr>
<td>( H_0 ) (normal) : ( SPE(k) &lt; SPE_\alpha )</td>
<td>Reject ( H_0 ) (Accept ( H_1 ))</td>
</tr>
<tr>
<td>( H_1 ) (abnormal) : ( SPE(k) \geq SPE_\alpha )</td>
<td>Accept ( H_0 ) (Reject ( H_1 ))</td>
</tr>
</tbody>
</table>

\( H_0 \) is true (\( H_1 \) is false) | Type I error (false alarm) | Correct
\( H_0 \) is false (\( H_1 \) is true) | Correct | Type II error (miss detection)

The bandwidth parameter can be determined by k-fold cross validation.

AAKR: auto-associative kernel regression
Results of tube leakage detection (250 MW drum-type boiler)

- Leakage detection before unscheduled shutdown
- Contribution analysis for faulty variable identification

\[ \overline{SPE}(k) = \lambda SPE(k) + (1 - \lambda)SPE(k-1), \quad \text{for } k > 1 \]
\[ SPE(1) = SPE(1), \quad \lambda = 2/(w+1) \]
Previous research topics in KINCO using data-driven techniques

- Knowledge Creation of e-Manufacturing
- Ozone Forecasting
- Wafer Ingot Process
- Parameter Estimator
- Feedback countermeasures (control process/diagnose faults)
- Quality Predictor
- Diagnosis of Motor
- Contents Recommendation (Ubiquitous Robot Companion)
- Contents Recommendation
- Sensor-Fusion Autonomous Guided Vehicle
- Oil Content Measuring System
- Non-precipitation Echo Detection
- Water Treatment Process
- Diagnosis of Motor
- Contents Recommendation (Ubiquitous Robot Companion)
Today, the industry has its fourth revolution, Industry 4.0 or Cyber-Physical systems. The first revolution was the use of steam and water power, next came the concept of a production line and division of labor that was supported with the usage of electric power in manufacturing. This revolution resulted in mass manufacturing. The third revolution was driven by information technology and automation. PLCs (Programmable Logic Controllers, special programmable devices for industrial automation), computers and robots entered the production floor of factories. In Industry 4.0 everything will will be connected and will be digitized. Personalization driven by the end-user, waste prevention and sustainability are important goals.

Topics presented by the panelists:

Gil Gonçalves: “Will robotics and artificial systems completely replaced the human operator in production?”

Sungshin Kim: “Multivariate statistical techniques for fault detection and diagnosis of large-scale industrial processes.”

Heinz Woern: “Intelligent robots for Intelligent Manufacturing-Industry 4.0”

Several question were raised by the panelists: the role of the human in future manufacturing, the cooperation of robots and humans, combination of possibilities and technologies, how to manage data and to build knowledge?

After the introduction of the panelists several topics were discussed.

The human worker will not disappear but a different type of worker will be needed. The new worker in the industry will be highly educated and having a broad view over the manufacturing process. Robots will become more intelligent, will be more human like, will learn and build a knowledge-base. So robots are more apt to do the dirty, dull and dangerous work. Cooperation with humans is an important aspect, because now most industrial robots are separated from places were humans operate, mostly because of security. Same situation will arise in the situation where autonomous cars will enter the domain of traffic.

The business model for manufacturing could also change by new techniques and network based solutions that can be on demand. This might result in zero waste, reuse and sustainability.

The last topic of discussion was security. The common idea among the panelists and people in the audience was that this is still underestimated. Most systems are built and security is added afterwards. Security is missing in the design. 100% security is not possible, but today, the vulnerability if IT systems is high. A solution could be a design that includes graceful degradation. This means that a plant will still work when it is infected by malware. Perhaps some work has to done manually, but the system as a whole should not stop functioning as is now sometimes the case.