Smart Maintenance in Cyber-Physical Systems

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Aim and outline

Aim of this presentation:
To present concepts that enable Smart Maintenance in Cyber-physical systems

Outline:
1. Cyber-physical systems
2. Smart Maintenance
3. Application of Smart maintenance in cyber-physical systems
4. Summary & Conclusion
1. Cyber-physical systems

Age of sail

Steam engine
1838: SS Great western
1911: Selandia
1966: DNV E0
1969: M/S Taimyr

Diesel engine
1937: 167 men for operating an engine room!

Instrumentation & automation of Engines

MUNIN project

2012: Concept project for deep sea vessel

1961: M/S Kinkasan Maru
1. Cyber-physical systems

**Figure 1:** Four stages of industrial revolutions
Picture 1 collected from “1983 Industrial Robots KUKA IR160/60, 601/60”
1. Cyber-physical systems

- Definition of Cyber-Physical systems (CPS) (Lee, Bagheri, & Kao, 2015): “Transformative technologies for managing interconnected systems between its physical assets and computational capabilities.”

ICT systems:
Maintenance scheduled on time intervals

Virtual world

CPS:
Convergence of the physical and virtual world

Physical world

Equipment:
Visual inspections, manually registered before sent to the virtual world.
1. Cyber-physical systems

Example of an architecture for CPS:

Figure 2: Architecture model for predictive maintenance (Source: Rødseth et. al., Euromaintenance 2016)
2. Smart Maintenance

• German Standardization Report for Industry 4.0 (DIN, 2016):
  “In Industry 4.0 in general, and specifically in the factory of the future – the smart factory – **maintenance will play a central role** as the guarantor of the availability and reliability of machines and systems... Without systematic development of maintenance into smart maintenance, the successful implementation of Industry 4.0 will be put at risk.”

• Research priorities from the EU project Focus (www.focusonfof.eu): Optimized & Predictive Maintenance.

• Maintenance in digitalized manufacturing (Bokrantz et. al., 2017): Fact based maintenance planning.
2. Smart Maintenance

Figure 3: Industry 4.0 maturity model, adapted from (Nienke et.al., 2017) and (Schuh et. al., 2017)
### 2. Smart Maintenance

**Table 1:** The main value drivers for Industrie 4.0 adapted from (McKinsey&Company, 2015).

<table>
<thead>
<tr>
<th>Activities and technology</th>
<th>Service/aftersales</th>
<th>Asset utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Remote maintenance</td>
<td>Remote monitoring and control</td>
</tr>
<tr>
<td></td>
<td>Predictive maintenance</td>
<td>Predictive maintenance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Augmented reality for MRO</td>
</tr>
<tr>
<td>Indicative impact</td>
<td>10-40 % reduction of maintenance costs</td>
<td>30-50% reduction of total machine downtime</td>
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</tbody>
</table>
2. Smart Maintenance

- **Predictive maintenance** (En 13306, 2010): “Condition based maintenance carried out following a forecast derived from repeated analysis or known characteristics and evaluation of the significant parameters of the degradation of the item”
2. Smart Maintenance

Condition-based maintenance

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Prognosis (Predictive maintenance)</th>
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<tbody>
<tr>
<td>Physical-based</td>
<td>Experience-based</td>
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</tbody>
</table>

**Physical-based:**
- Vibration analysis
- Magnetism monitoring
- Diesel Engine modelling
- Tribology analysis
- Process parameters analysis

**Experience-based:**
- Performance monitoring of engine
- Visual inspection

**Data-driven:**
- Artificial Neural Networks (ANN)
- Statistical models, e.g. Statistical Process Control

Source: Asmai, S.A. et. al (2010) 2nd International Conference on Computer Research and Development
2. Smart Maintenance

- Machine learning teaches computers where several algorithms “learn” directly from data.
- Evolvement from Artificial Intelligence.
- Data is king with Moores Law.
2. Smart Maintenance

In *computerized maintenance management system* (CMMS):
Planned repair process, e.g. in SAP:
1. Notification: Technical object, date, description, priority
2. Planning: Work to be performed, material, tools, resource internal/external
3. Controlling: Order release, capacity leveling, paper printout, availability check
4. Implementation: Material withdrawal, external procurement
5. Completion: Time confirmation, technical completion & confirmation

Record of history:
Material usage, orders, notifications, information system, usage list
2. Smart Maintenance

What time window is needed in the maintenance system?

![Capacity overview in CMMS, e.g. in SAP](chart.png)
3. Application of Smart maintenance in cyber-physical systems

**Figure 4:** PLI calculations

3. Application of Smart maintenance in cyber-physical systems

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Source:
3. Application of Smart maintenance in cyber-physical systems

Source:
4. Summary & conclusion

- Smart Maintenance applied in land based industry has been presented with a case of predictive maintenance.
- The benefit is to perform maintenance when actually needed.
- A challenge is to have sufficient relevant data for machine learning.
- To Transfer this Smart Maintenance into the maritime sector several issues must be reviewed:
  - The cost of 128 kbs bandwidth as satellite service (MUNIN vessel) for notifying a future maintenance action at deep sea. This service is a shared cost. Should this bandwidth be increased? How much data is actually necessary to transfer from vessel to shore?
  - Is the machinery equipped with sensors measuring sufficient data quality?
  - Big data analytics on device (at the vessel) or in cloud (at shore)?
  - To what extent has the maritime industry willing to share anonymous fleet data?
  - If Shipping 4.0 permits manning of vessel, which maintenance tasks can be performed during voyage?
The End

“Coming together is a beginning, staying together is progress, and working together is success.”

-Henry Ford-

Thank you for your attention!

Reference of open access publication

Available at: https://doi.org/10.1007/s40436-017-0202-9