Machine Learning in Production Planning and Control: A Literature Review

Juan Pablo Usuga Cadavid: juan_pablo.usuga_cadavid@ensam.eu
Samir Lamouri: samir.lamouri@ensam.eu
Bernard Grabot: bernard.grabot@enit.fr
Arnaud Fortin: a.fortin@ifakt.com

26èmes journées STP du GDR MACS Clermont-Ferrand, 22-23 novembre 2018
Production Planning & Control (PPC), context in Industry 4.0

Manufacturing context:

- 67% of the companies from high-wages countries claim that the adherence to the delivery dates is their main logistical target
- They struggle to achieve that due to machine failures, missing raw materials or short-term customer changes
- Prerequisite to reach logistical targets → Excellent PPC processes

(Reuter et al., 2016)
Production Planning & Control, challenges in Industry 4.0

Production Planning & Control (PPC)
Research objectives (1/2): how to implement ML-aided PPC

Mandatory Elements of a Method (Zellner, 2011)

- Procedure
- Techniques
- Results
- Roles
- Information Model

Which are the activities, techniques and tools used to deploy ML-aided PPC?
Research objectives (2/2): where to find the data?

Which are the commonly used data sources when implementing a ML-aided PPC?

Tao et al. (2018)
Literature review methodology

Used keywords

AND

("Deep Learning" OR "Machine Learning")

• ("Production scheduling")
• ("Production control")
• ("Line Balancing")
• ("Production Planning")

Results

<table>
<thead>
<tr>
<th>Step</th>
<th>Science Direct</th>
<th>SCOPUS</th>
<th>Kept Articles</th>
<th>Excluded</th>
</tr>
</thead>
<tbody>
<tr>
<td>First results</td>
<td>1538</td>
<td>611</td>
<td>2149</td>
<td>0</td>
</tr>
<tr>
<td>Year &gt;= 2011</td>
<td>761</td>
<td>356</td>
<td>1117</td>
<td>1032</td>
</tr>
<tr>
<td>Only &quot;Research Articles&quot; (Science Direct)</td>
<td>606</td>
<td>299</td>
<td>905</td>
<td>212</td>
</tr>
<tr>
<td>&quot;Conference Paper OR Article&quot; (SCOPUS)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Title and Abstract Review</td>
<td>46</td>
<td>24</td>
<td>70</td>
<td>835</td>
</tr>
<tr>
<td>Duplicates removal</td>
<td>32</td>
<td>15</td>
<td>47</td>
<td>23</td>
</tr>
<tr>
<td>Full text analysis: short list</td>
<td>27</td>
<td>13</td>
<td>40</td>
<td>7</td>
</tr>
</tbody>
</table>
Results (1/5): use types overview

Use types

<table>
<thead>
<tr>
<th>Domain type</th>
<th>% of number of uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart Planning and scheduling</td>
<td>55%</td>
</tr>
<tr>
<td>Time Estimation</td>
<td>20%</td>
</tr>
<tr>
<td>Quality Control</td>
<td>3%</td>
</tr>
<tr>
<td>Process Design</td>
<td>5%</td>
</tr>
<tr>
<td>Process Control and Monitoring</td>
<td>3%</td>
</tr>
<tr>
<td>Inventory &amp; Tools Control</td>
<td>8%</td>
</tr>
<tr>
<td>Fault Prediction &amp; Diagnosis</td>
<td>8%</td>
</tr>
</tbody>
</table>

Most recurrent domains to perform PPC with ML

Scarce results coupling these domains with ML-aided PPC
Results (2/5): activities

11 key activities were identified

- **Data Acquisition System Design and Integration**: Included 13%, Not Included 88%
- **Data exploration**: Included 93%, Not Included 8%
- **Data Cleaning & Formatting**: Included 35%, Not Included 65%
- **Feature Selection**: Included 73%, Not Included 28%
- **Feature Extraction**: Included 70%, Not Included 30%
- **Feature Transformation**: Included 80%, Not Included 20%
- **Hyper parameter tuning**: Included 38%, Not Included 62%
- **Model Training, Validation and Testing**: Included 13%, Not Included 88%
- **Model Update through new data**: Not Included 93%, Included 8%
- **Model Comparison and selection**: Included 35%, Not Included 65%
- **Contextualized Results Analysis or Application**: Not Included 50%, Included 50%
Results (3/5): techniques

% of publications by used learning types

- 1 Learning Type: 25%
- 2 Learning Types: 73%
- 3 Learning Types: 3%

Number of uses per technique

- Clustering: 14
- Tree-based model: 12
- Neural Network: 10
- Q-Learning: 8
- Regression: 6
- SVM: 4
- PCA: 2
- Association Rule: 0
- Bayesian Models: 0
- Sarsa: 0

Number of uses per year in top 3 techniques

- Neural Network
- Clustering
- Tree-based model
Results (4/5): tools

<table>
<thead>
<tr>
<th>Tools</th>
<th>Number of uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not Mentioned</td>
<td>17</td>
</tr>
<tr>
<td>R</td>
<td>5</td>
</tr>
<tr>
<td>MATLAB</td>
<td>4</td>
</tr>
<tr>
<td>Python</td>
<td>3</td>
</tr>
<tr>
<td>RapidMiner</td>
<td>3</td>
</tr>
<tr>
<td>Tensorflow (Python based)</td>
<td>2</td>
</tr>
<tr>
<td>WEKA</td>
<td>2</td>
</tr>
<tr>
<td>ACE Datamining System</td>
<td>1</td>
</tr>
<tr>
<td>Clementine</td>
<td>1</td>
</tr>
<tr>
<td>Keras (Python based)</td>
<td>1</td>
</tr>
<tr>
<td>Neural-SIM</td>
<td>1</td>
</tr>
<tr>
<td>Visual C++</td>
<td>1</td>
</tr>
<tr>
<td>Xelopes Library</td>
<td>1</td>
</tr>
</tbody>
</table>
Results (5/5): Data source utilization

- **Management data**: 55% Used, 45% Other data sources
- **Equipment data**: 83% Used, 18% Other data sources
- **User data**: 100% Used, 0% Other data sources
- **Product data**: 85% Used, 15% Other data sources
- **Public data**: 83% Used, 18% Other data sources
- **Research data**: 65% Used, 35% Other data sources

Juan Pablo Usuga Cadavid, Samir Lamouri, Bernard Grabot, Arnaud Fortin
Further research

• Develop a Robust Procedure to implement ML-aided PPC → Give an order to different activities

• Link techniques and tools to activities (set the basis to an Information Model)

• Test both previous points with an application
Questions?
References
