Heavy Equipment Demand Prediction with Support Vector Machine Regression Towards a Strategic Equipment Management

Dubai, 04.12.2016
International Conference on Architecture, Materials and Construction
Dipl.-Ing. Amadeusz Kargul
Agenda

1. Introduction
2. Strategic Construction Equipment Management
3. Demand Prediction Approach
4. Results and Discussion
Agenda

Introduction

Strategic Construction Equipment Management
Introduction

Digitization of construction industry

All industries

- Challenges and chances in the use of communication and information technologies to increase added value

Construction industry with focus on heavy-equipped construction processes

- Efficiency potentials through the transmission and processing of construction machines condition and operation data

Current Approaches focus either on

- condition monitoring -> life cycle based
- process monitoring -> project based
- resource planning? life cycle cost analysis?

Fleet management systems (FMS):

- Planning, monitoring and controlling of construction machines by different stakeholders using a local software application or a web-based application by recording and processing telematics data.

General Research Gap

Lack of holistic life cycle based fleet management regarding resource planning, condition and process monitoring and cost controlling
Introduction

Strategic Construction Equipment Management

Demand Prediction Approach
Strategic Construction Equipment Management

Holistic approach for planning, monitoring and controlling construction machines over their lifecycle.

- **Ressources-Module**
  - Condition-based monitoring
  - Maintenance Management
  - Ressource allocation
  - Project-based Monitoring
  - Project communication

- **Controlling-Module**
  - Maintenance and repair cost
  - Life cycle cost analysis
  - Project cost controlling

- **Lifecycle construction machine**
Strategic Construction Equipment Management

Holistic approach for planning, monitoring and controlling construction machines over their lifecycle
Strategic Construction Equipment Management

Demand Prediction Approach

Results and Discussion
Demand Prediction Approach

Focus today

- **Condition-based monitoring**
  - **Maintenance management**
  - **Ressource allocation**

- **Project-based Monitoring**
  - **Project communication**

**Ressources-Module**

**Controlling-Module**

- **Maintenance and repair cost**
- **Life cycle cost analysis**
- **Project cost controlling**

**Lifecycle construction machine**
Demand Prediction Approach

Key requirement for strategic equipment management is the knowledge of construction machine demand for future construction projects

- **Forecast** of monthly utilization rates for specific construction machine groups
- **Data-driven support** for construction machine owners regarding resource planning
- **Current construction machine stock:** Increasing planning safety and transparency of entire machine owner’s fleet for utilization on projects respectively for maintenance management
- Prerequisite for **short term** (rent needed machine for a short time period) and **long term procurement strategy** (buying / leasing)

**Monthly utilization rate for machine groups (excavator, dozer, wheel loader, …):**

\[
\frac{\text{used workdays per month of construction machine}}{\text{possible workdays per month of construction machine}}
\]

\[
\frac{\text{used workdays per month of construction machine group}}{\text{possible workdays per month of construction machine group}}
\]
Demand Prediction Approach

Support Vector Machines

Support Vector Machines (SVM) are a supervised machine learning algorithm for classification and regression through pattern recognition.

**Core idea** of SVM is to map a training data set (input space) into a higher dimensional feature space by applying a kernel function and construct a hyperplane with maximum margin in the feature space.

SVM Regression fits a nonlinear function (e.g. construction machine demand) with an n-dimensional hyperplane within plus/minus Epsilons as maximum margins and slack variables for outcluding training data outliers.
Demand Prediction Approach

Support Vector Machine Regression

SVMR features for month x to be predicted

- Month x
- Past utilization rate for month x-1 and x-2
- Planned contract volume for month x
- Planned machine cost for month x
- Number of school holiday for month x

Feature data set 2013-2015

Learning / training data set 2013-2014

Test data set 2015

Data set resources
- Planned machine cost of 10 medium sized excavators of 111 small sized construction projects (planned contract volume with total: 50 Mio. €)
- Past utilization rates between 2013 and 2015
Demand Prediction Approach

Results and Discussion
Results and Discussion

High prediction rate enabled

SVMR utilization rates prediction of the construction machine group hydraulic excavator (weight class: 6 - 12 tons) for the year 2015 in relation to the real world values

The SVMR prediction shows a good approximation of the real world utilization rates. Compared to the historical mean, it can be stated that the deviation between real world utilization rate and historical mean value is higher over the entire year.

Goodness-of-fit with over 80 percent shows a proper value for R-squared. Mean squared error and the root mean squared error show a less prone to error prediction compared with the historical mean approach.

<table>
<thead>
<tr>
<th></th>
<th>SVMR</th>
<th>Historical mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSE</td>
<td>0.012</td>
<td>0.016</td>
</tr>
<tr>
<td>RMSE</td>
<td>0.108</td>
<td>0.127</td>
</tr>
<tr>
<td>R-square</td>
<td>0.804</td>
<td>0.730</td>
</tr>
</tbody>
</table>
Results and Discussion

Further things to do

**Demand prediction approach:**
- More features for improving prediction rate respectively enabling an automated feature selection and testing

**General strategic equipment approach:**
- Development and linkage of all presented fleet management modules for a holistic construction equipment management

Summary
- Introduction presents the general shortcomings and future challenges of construction equipment management
- Presentation of the general research approach regarding a strategic construction equipment management
- Demand prediction approach of heavy equipped construction machines as key task of resources module
- Discussion of results and further research steps
Thank you!

Prof. Dr.-Ing. Dipl.-Wi.-Ing. Willibald A. Günthner

Prof. Dr.-Ing. Johannes Fottner

Technische Universität München
fml - Lehrstuhl für Fördertechnik
Materialfluss Logistik