Towards Optimized Machine Operations by Cloud Integrated Condition Estimation

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Abstract. The requirements concerning the Overall Equipment Effectiveness (OEE) – especially machine availability – increase constantly in production nowadays. Unplanned down-times have to be prevented by efficient methods. Predictive, condition based maintenance represents a valuable approach for fulfilling these demands. Existing concepts lack of information, training data or interconnectedness. The objective of this paper is to present a novel approach in the context of Industrie 4.0 by using machine models with integrated uncertainties in the beginning, resolving these by methods of machine learning during operation and integrating both into a cloud-based service architecture.

Keywords: condition monitoring, machine learning, state estimation, cloud

1 Introduction

Nowadays production systems are subject to significant complexity with high demands for availability, efficiency or costs [1]. Especially machine availability is a strict requirement since it is strongly connected to increasing the added value. Although condition monitoring together with predictive maintenance represents a good approach in order to avoid unplanned down-times, process interruptions due to wear do not lead to component failure in the first place. In fact the complexity of the overall system causes different interruptions like inaccurate positioning of mechanical parts or diminished force transmission.

As the basis for condition monitoring components with risk of default like bearings, belts or drives are continuously monitored, often in a sporadic and manual way [2]. By using powerful algorithms multistage warnings and down-times can be derived for condition-based maintenance, which results in lower economic damages than unplanned failures (secondary damage, loss of production).

In the context of Industrie 4.0 intelligent maintenance is one of the encouraged use cases [3]. In order to realize flexible, dynamic and self-optimizing production Cyber-physical systems are the indispensable basis for building Cyber-physical production systems (CPPS) [4; 5]. At the same time the adaption of existing technologies like cloud computing for enabling local CPPS with global intelligence is absolutely necessary [6; 7]. Furthermore cloud computing is named as one of the key technologies for

software-defined platforms and service platforms [8] and foreseen as a disruptive technology for present manufacturing [9].

Putting all these facets of Industrie 4.0, cloud computing, Internet of Things, Internet of Services together the following paper presents a novel approach for cloud integrated condition estimation for optimized machine operations. It begins with a short overview on existing condition monitoring solutions and methods for intelligent state estimation and describes some existing approaches concerning cloud-based reference-architectures. Afterwards state estimation of a belt in a tubular bag machine as a use case for applying methods of machine learning is focused. While wear of components cannot be sufficiently modeled during engineering phase of the system, estimation during operation leads to resolved uncertainties in the machine model. Finally an approach for integrating algorithms and models in a cloud architecture to archive intelligent maintenance is discussed.

2 State of the Art

Up-to-date condition monitoring solutions mainly use online data measurement and aggregation for observing dynamic processes. Usually both internal data from controls (current, torque, speed, e.g.) and external sources (vibration, temperature, e.g.) are considered. By now different approaches and products exist, which will be provided as an overview in the following.

The high grade of technology in production machines and the used measurement and analysis hardware for condition monitoring result in extensive additional costs. Therefore many of the existing solutions address large systems like (wind) power plants, mining or rolling mills where down-times lead to enormous economic losses.

However availability of smaller production systems is increasingly important raising the need for monitoring as well. Usual methods for determining a plant’s state are vibration analysis, thermography, vibro-acoustic approaches or oil analysis [10]. Commercial applications often integrate necessary sensors as well as elaborate algorithms. Examples for such systems are “Ω-Guard“ by Bachmann, “@ptitude Asset Management System“ by SKF, “Real Time Maintenance” by ifm or “SIPLUS CMS“ by Siemens.

The majority of commercial products for condition monitoring tasks are applied locally for specific tasks without connection to superior systems and require some time for self-parametrization (learning phase) or configuration by any user.

Many approaches for optimizing condition monitoring are state of research. [11], for example, introduces local monitoring methods for primary components of machine tools like spindles, ball screws and linear guiding. [2] focuses on packaging machines. After the identification of standard wear parts methods and strategies for predictive maintenance by frequency analysis (Peak to Peak, RMS-FFT, frequency selective FFT) are developed. The results are transferred into a platform, which constitutes an exchange of data and expert knowledge above companies’ boundaries.

Intelligent machine learning methods for predictive analytics are used in different applications like monitoring drilling processes in oil and gas industry [12] or identify-