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Semantic framework for predictive maintenance in a cloud environment

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Abstract

Proper maintenance of manufacturing equipment is crucial to ensure productivity and product quality. To improve maintenance decision support, and enable prediction-as-a-service there is a need to provide the context required to differentiate between process and machine degradation. Correlating machine conditions with process and inspection data involves data integration of different types such as condition monitoring, inspection and process data. Moreover, data from a variety of sources can appear in different formats and with different sampling rates. This paper highlights those challenges and presents a semantic framework for data collection, synthesis, and knowledge sharing in a Cloud environment for predictive maintenance.

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Keywords: Predictive maintenance; Knowledge management; Cloud manufacturing;

1. Introduction

Maintenance plays an important and supportive role in the production. Effective maintenance policy improves quality, efficiency, and effectiveness of manufacturing operation and could influence the productivity and profitability of a manufacturing process [1]. Diagnostics and prognostics are two important aspects in a Condition-based Maintenance (CBM) program [2]. In literature several approaches for machining operation and machine tool condition monitoring have been reported [3].

To improve diagnostics and prognostics for better maintenance decision making, there is a need to better correlate process and inspection data with machine condition to differentiate between process and machine degradation [4]. Generally, diagnostics and prognostics models require significant amounts of historical condition monitoring and event data, as the uncertainty of these models decreases when data become more extensive. The means to synthesise smaller available data sets to generate extensive, representative historical condition monitoring and event data sets remains an open research question [5].

To solve those problems more detail information about manufacturing asset across its lifetime need to be gathered, accessed and processed. Targeting cloud-based predictive maintenance, this research aims at developing a semantic framework for the context-aware approach.

The remainder of the paper is organised as follows. Section 2 reviews background. Section 3 highlights available sources of data and benefits of its aggregation. Proposed semantic framework is presented in Section 4. Section 5 provide an example how this framework can be used to retrieve relevant information. Finally, Section 6 conclude the paper.

2. Backgrounds

2.1. Disparate data sources

Development and implementation of Information and Communication Technologies (ICT) in the industry in past decade brings new possibilities and challenges. More data are gathered, however, stored and processed in disparate and heterogeneous systems as Computerised Maintenance Management System (CMMS) for maintenance record-keeping, Condition Monitoring (CM) for asset health state

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monitoring and Supervisory Control and Data Acquisition (SCADA) systems for monitoring process and controlling the asset.

2.2. Industry 4.0

According to the Federal Ministry of Education and Research, Germany (BMBF) after Monostori [6], "Industry is on, the threshold of the fourth industrial revolution frequently noted as Industry 4.0. This revolution is led by development and implementation of Cyber-Physical Systems. A similar concept is also researched under the name of Cloud Manufacturing. Cloud Manufacturing paradigm is a result of a combination of cloud computing, the Internet of Things, service-oriented technologies and high-performance computing [7]. It transforms manufacturing resources and capabilities into manufacturing services. It is not the simple deployment of manufacturing software tools in the computing cloud. The physical resources integrated into the manufacturing cloud are able to offer adaptive, secure and on-demand manufacturing services over the Internet of Things [8].

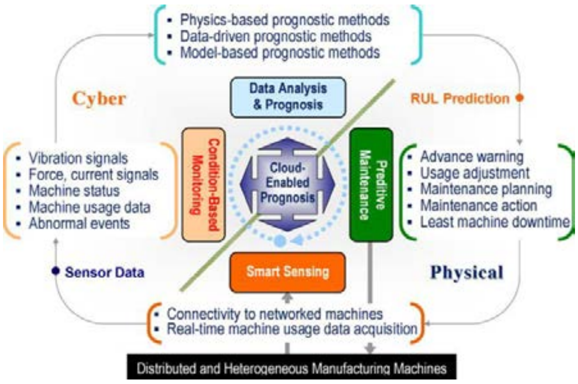

Fig. 1. Cloud-enabled monitoring, prognosis and maintenance [5].

Overview of cloud-enabled prognostics approach within cyber-physical concept has been visualised in Fig.1. Cloud-enabled prognosis benefits from both advanced computing capability and information sharing for intelligent decision-making [5].

2.3. Context

Recently a context awareness is an approach gaining more focus from researchers in the field of CBM and predictive maintenance. This well-known concept in some other fields could be beneficial when employed in CBM and Asset Management [9].

2.3.1. Context definition

In predictive analytics, two sets of information can be distinguished namely condition monitoring and context. Condition monitoring data are used to estimate health state of monitored equipment while context information provides support for a better understanding of it. Context information consists of two types of factors: conditions that affect health state estimation, and condition that affects degradation processes. An example of factors that belongs to the first context group is types of used sensor, acquisition parameters, and operational condition at measurement time. Operational conditions and performed maintenance actions are the examples of contextual information belonging to the other group. Overview of different context modelling techniques and its usage in predictive maintenance has been reported in [10].

2.4. Ontology

In computer and information science, ontology determines formal specifications of knowledge in a domain explicit specification of the objects, concepts, and other entities (vocabulary) that exist in some area of interest and the relationships that hold among them [11]. Ontology model O can be described as a set O={C, RS, I}, where C is a collection of concepts in the ontology called also classes, I is set of particulars (instances of classes, individuals), and RS is set of relations between two concepts or particulars. Ontology Web Language (OWL) [12] is one of common ontology formalization languages. Reasoning over ontology specified with OWL is done with the use of Descriptive Logics that makes it more powerful than just reasoning within Resource Description Framework (RDF), as more complicated relations can be represented. Moreover, Semantic Web Rule Language (SWRL) [13] extend the capability of OWL to represent knowledge by means of more complex rules. According to [14], ontology-based context modelling allows:

- Knowledge sharing between computational entities by having a common set of concepts about the concept;
- Logic inference by exploiting various existing logic reasoning mechanisms to deduce high-level, conceptual context from low-level, raw context;
- Knowledge reuse by reusing well-defined Web ontologies of different domains, e.g. a large-scale context ontology can be composed without starting from scratch.

2.4.1. Standards

There are some standardisation initiatives to enable the integration of disparate maintenance IT systems.

MIMOSA (Machinery Information Management Open Systems Alliance) [15] is a not-for-profit trade association dedicated to developing and encouraging the adoption of open information standards for Operations and Maintenance in manufacturing, fleet, and facility environments. MIMOSA's open standards enable collaborative asset lifecycle management in both commercial and military applications. OSA-EAI (System Architecture for Enterprise Application Integration), OSA-CBM (Open Systems Architecture for Condition Based Maintenance), MIMOSA standards are compliant with and form the informative reference to the published ISO 13374-1 standard for machinery diagnostic systems. According to [16] MIMOSA and OSA-CBM are the most evolved standards that cope with CBM technology.