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Procedia CIRP 38 (2015) 53 – 57

www.elsevier.com/locate/procedia

The Fourth International Conference on Through-life Engineering Services

Condition monitoring in the cloud

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Abstract

Due to the very high demands on availability and efficiency of production systems and industrial systems, condition-based maintenance is becoming increasingly important. The use of condition monitoring approaches to increase the machine availability and reduce the maintenance costs, as well as to enhance the process quality, has increased over the last years. The installation of industrial sensors for condition monitoring reasons is complex and cost-intensive. Moreover, the condition monitoring systems available on the market are application specific and expensive. The aim of this paper is to present the concept of a wireless sensor network using Micro-Electro-Mechanical Systems – MEMS sensors and Raspberry Pi 2 for data acquisition and signal processing and classification. Moreover, its use for condition monitoring applications and the selected and implemented algorithm will be introduced. This concept realized by Fraunhofer Institute for Production Systems and Design Technology IPK, can be used to detect faults in wear-susceptible rotating components in production systems. It can be easily adapted to different specific applications because of decentralized data preprocessing on the sensor nodes and pool of data and services in the cloud. A concrete example for an industrial application of this concept will be represented. This will include the visualization of results which were achieved. Finally, the evaluation and testing of this concept including. implemented algorithms on an axis test rig at different operation parameters will be illustrated.

Peer-review under responsibility of the Programme Chair of the Fourth International Conference on Through-life Engineering Services.

Keywords: Condition monitoring; algorithms; wireless sensor network; classification

1. Introduction

Due to the very high demands on availability and efficiency of production systems and industrial systems, condition monitoring is becoming increasingly important. The use of condition based maintenance approaches to increase the machine availability and to reduce the maintenance costs, as well as to enhance the process quality, has increased over the last years.

The installation of industrial sensors is very costly and can be demanding due to cable communication issues and access to the component under consideration. These are also too expensive and need additional hardware and software, in order to enable communication, data acquisition and conditioning for additional applications, such as condition monitoring.

Moreover, the condition monitoring systems available in the market are cost-expensive and mostly designed only for application specific use. The implementation of a wireless sensor network for condition monitoring applications can increase the adaptability and flexibility of its use for manifold applications. They will enable the distributed data preprocessing, feature extraction and classification on the sensor node. Furthermore, intelligent algorithms for fault detection and diagnosis can be implemented on the sensor node level, which allows decentralized data processing [1].

In addition, the main industrial sensors available in the market are wired and very expensive, and have normally little or no intelligence. Therefore, the industry sensors are less

Peer-review under responsibility of the Programme Chair of the Fourth International Conference on Through-life Engineering Services.
doi:10.1016/j.procir.2015.08.075

suitable for many condition monitoring applications. In comparison, Micro-electro-mechanical systems (MEMS) sensors are cost-effective, highly integratable. Besides, they consume less energy and are highly configurable [2,3].

2. Vibration sensor based on MEMS accelerometer for condition monitoring

The most common technique used for condition monitoring of wear-susceptible rotating components is the diagnosis based on vibration data (e.g. acceleration or acoustic emission) [4,5]. In a research project, a MEMS based wireless sensor network for fault detection and diagnosis was used [6]. A condition monitoring application of a ball screws in industrial plants using wireless sensor concepts is published in [7].

In [8] the suitability of the MEMS for condition monitoring applications was investigated. The results obtained were satisfactory and confirm that MEMS sensors can be used to acquire data for condition monitoring. However, their range of application is limited, for instance, because of the sensitivity to humidity.

Nevertheless, the use of MEMS sensors with associated development board, such as Raspberry Pi 2, Arduino R3 and Beagle Bone Black for monitoring of wear-susceptible rotating components can be an alternative to the very expensive condition monitoring solutions available on the market, which use industrial sensor data.

3. Concept of the wireless sensor network

To increase the machine availability and reduce the downtime as well as the maintenance costs, a wireless sensor network for condition monitoring is installed. It is composed of four individual nodes, which can act independently from each other. Each of these nodes disposes of a MEMS temperature and vibration sensor. A MEMS digital output motion sensor with 3-axes "nano" accelerometer is used. The specification of this sensor is showed in the table 1.

Table 1. The MEMS Sensor specification 1.

MEMS sensor LIS3DH specification	
Measuring accelerations with output data rates from	1 Hz to 5 kHz
Wide supply voltage	1.71 V to 3.6 V
Ultra low-power mode consumption	< 2 µA
Dynamically selectable full-scale	±2g/±4g/±8g/±16g
Data output	16 bit
Operating range	-40 °C to +85 °C
Shock survivability	10000 g
Digital output interface	I2C/SPI

Fig. 1 shows a simplified schematic structure of the wireless sensor network, which is implemented on the axis test rig.

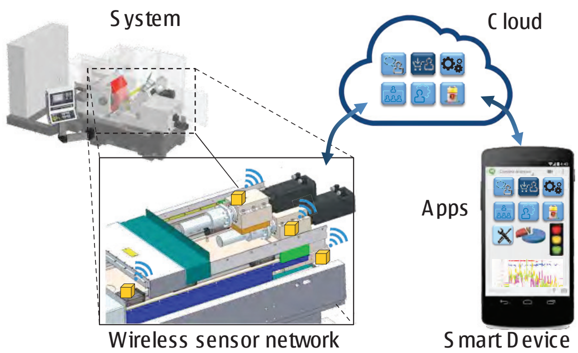

Fig. 1 Wireless sensor network on the production system.

The concept presented in Fig. 1 consists of the wireless sensor network, which includes a MEMS vibration sensor, a minicomputer (Raspberry), the cloud (including services) and a smart device for remote access and visualization.

The data acquisition and processing is realized on the sensor node level. Furthermore, the classification of the features extracted from the diagnosis signal is transmitted to the cloud server. On the cloud server there are applications and services available for maintenance planning, remote condition monitoring, etc.

Via smart device the service technician or maintenance planner can receive the reports generated using a condition monitoring processing unit. This allows remote continuous monitoring of the production system and enables condition-based maintenance decision making of the system concerned.

4. Distributed condition monitoring on wireless sensor network and in the cloud

The steps of pattern recognition on the sensor node include data acquisition, signal preprocessing, feature extraction and selection and classification.

Firstly, the vibration data are collected using a MEMS vibration sensor with a sampling rate of 3000 Hz.

In the second step, the raw data are preprocessed using different methods, such as low-pass filtering and Fourier transform. Then, the features from the preprocessed signals are extracted. Feature extraction can be done by calculating characteristic signal parameters. These are for example, statistical features, such as, variance, Root mean square (RMS) value, kurtosis, skewness, etc. In the next step, suitable features are selected. This step affects the classification results. Therefore, the selection of proper features can increase the Support Vector Machine (SVM) performance, which was implemented for data classification. For this reason, *sequential feature selection* method is used to identify the suitable features [9].

After the classification of the features is successfully completed, the result from each sensor node is transmitted to the cloud. If a component is damaged, it is detected and the service technician will be informed, so that the action needed