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Introduction

**Urko Zurutuza[1], Michele Albano[2], Erkki Jantunen[3],
and Luis Lino Ferreira[2]**

[1]Mondragon Unibertsitatea, Arrasate-Mondragón, Spain
[2]ISEP, Polytechnic Institute of Porto, Porto, Portugal
[3]VTT Technical Research Centre of Finland Ltd, Finland

Current advances in ICT are shaping the way we live and work. Current communication solutions allow people to be "always online, always connected", and similar technologies are applied to machine communication, also known as M2M communication. In particular, research and development efforts are devoted to extending the IoT to maintenance, thus providing ubiquitous access through the Internet to industrial systems under maintenance.

Two cornerstones for this (r)evolution, which is part of Industry 4.0, are the utilization of CPS in maintenance contexts, and leveraging data collected in the field by means of techniques from the Artificial Intelligence family. In this context, and based on these two cornerstone technologies, the MANTIS project (Cyber Physical System based Proactive Collaborative Maintenance) was born, to realize platforms that can perform CBM and PM in real industrial contexts.

In this vision, physical systems (e.g., industrial machines, vehicles, renewable energy assets) and the environment they operate in are monitored continuously by a broad and diverse range of intelligent sensors, resulting in massive amounts of data that characterise the usage history, operational condition, location, movement and other physical properties of those systems. These CPS form part of a larger network of heterogeneous and collaborative systems (e.g., vehicle fleets or photovoltaic and windmill parks) connected via robust communication mechanisms able to operate in challenging environments [Jantunen et al., 2017].

Sophisticated distributed sensing and decision-making functions are performed at different levels in a collaborative way ranging from (i) local nodes that pre-process raw sensor data and extract relevant information before transmitting them, thereby reducing bandwidth requirements of communication, (ii) over intermediate nodes that offer asset-specific analytics to locally optimise performance and maintenance, (iii) to cloud-based platforms that integrate information from ERP, CRM and CMMS systems and execute distributed processing and analytics algorithms for global decision-making [Jantunen et al., 2018].

The resulting technological ecosystem can empower methodologies such as CBM, which aims at predicting the condition of machinery based on the parameters or conditions of the equipment, in which some limits are established and the behaviour of such parameters are verified through different strategies. The objective of CBM is to provide the maximum objective data of the equipment to identify and avoid possible failures that could generate non-desired downtime in advance.

PM moves the bar one step further, and considers how the collected data have to be processed to extract more information, for example by allowing intelligent software to learn the behaviour of equipments in terms of the monitored parameters, and thus to identify outliers that correspond to potential problems. The modelling of faults can lead to the prognosis about the condition of machinery, comprising approximate information regarding when and how faults can present themselves given the current condition of the machine, the environment it is working in, and data collected on similar machines.

Throughout this book, authors mention both CBM and PM terms repeatedly.

As we have made clear here, CBM is based on using real-time data to prioritize and optimize maintenance resources. Observing the state of the system is known as condition monitoring. Such a system determines the equipment's health, and acts only when maintenance is actually necessary [Wikipedia]. The work in [Jardine et al., 2006] defines CBM as a maintenance program that recommends maintenance decisions based on the information collected through condition monitoring, consisting in three main steps: data acquisition (to get condition data), data processing and maintenance decision-making (to aid in diagnosis and prognosis functions).

Thus, PM uses a CBM strategy, and considers the detection and correction of root cause conditions that would otherwise lead to failure.

This introductory chapter draws a picture of the current trends in maintenance, and then summarizes the content of the rest of the book by providing hints to what PM can be and can do for the industry.

1.1 Maintenance Today

Maintenance in industry today focuses on aspects related to availability, profitability and safety [Holmberg et al., 2010; Paz and Leigh, 1994]. Companies wish to improve OEE, availability, performance and quality to supply better products, reducing the costs and increasing profitability and safety as much as possible [Ferri et al., 2012]. In fact, the economic importance of the machinery and equipment maintenance is huge, as hinted for example by the current average level of OEE is 50% i.e., there is a hidden factory behind every factory. The current view of the maintenance primary task is to keep the machinery and equipment constantly in working order to perform their intended functions [Swedish Standards Institute, 2010]. The definitions available in current literature are very close to each other and encompass the following basic assumptions [Mikkonen, 2009]:

- Maintenance tends to ensure that machinery remain in working order or that they are restored to normal operating condition;
- Maintenance includes all technical, administrative and management actions implemented during the lifetime of a machine.

The importance of condition monitoring is also highlighted in traditional industries, where the shortcomings in maintenance activities often end in decreased performance and quality. This obviously results in economic losses [Mikkonen, 2009]. Traditional maintenance methods are not cost optimised, and therefore new more effective means are being developed. In fact, maintenance today is moving in the direction of intelligent maintenance, and concepts such as CBM are gaining ground where efficiency is sought by means of information technology.

1.2 The Path to Proactive Maintenance

The main objective of MANTIS is set to "develop a Cyber Physical System based Proactive Maintenance Service Platform Architecture enabling Collaborative Maintenance Ecosystems".

For an optimum maintenance of assets, different systems and stakeholders have to share information, resources and responsibilities, in other words,

collaboration is required. Such a Collaborative Maintenance Ecosystem aims to:

- Reduce the adverse impact of maintenance on productivity and costs;
- Increase the availability of assets;
- Reduce time required for maintenance tasks;
- Improve the quality of the maintenance service and products;
- Improve labor working conditions and maintenance performance;
- Increase sustainability by preventing material losses (due to out-of-tolerance production).

PM commissions corrective actions aimed at sources of failure. It is designed to extend the life of mechanical machinery as opposed to 1) making repairs when often nothing is broken, 2) accommodating failure as routine and normal, and 3) pre-empting crisis failure maintenance – all of which are characteristics of the predictive/preventive disciplines.

A PM platform has to enable service-based business models and improved asset availability at lower costs through continuous process and equipment monitoring and data analysis. With this goal in mind, MANTIS also aims to identify and integrate critical information from other sources such as production, maintenance, equipment manufacturers and service providers. This service platform architecture has to take into account the needs of industries in the forefront of service-based business and operations as well as less mature ones, allowing improvements in maintenance to be achieved gradually and consistently.

The PM service platform consists of distributed processing chains that efficiently transform raw data into knowledge while minimising the need for transfer bandwidth. Chasing this overall objective gives raise to the need for a smart integrated domain knowledge system with advanced data monitoring, communication and analytics with self-learning capabilities, which themselves have to be overall dependable and secure. Thus, this chain includes key technologies such as (Figure 1.1):

- Smart sensors, actuators and cyber-physical systems capable of local pre-processing and local data storing/buffering;
- Robust communication systems for harsh environments;
- Distributed machine learning tools for data validation and decision-making;
- Cloud-based processing, analytics and data availability;
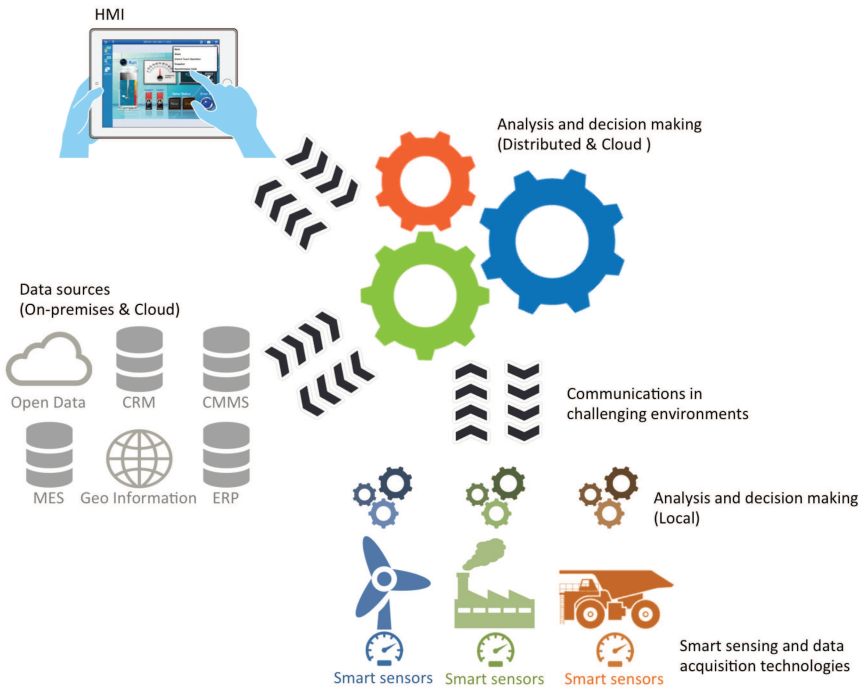- HMI to provide the right information to the right people at the right time in the right format.

Figure 1.1   Overall concept idea.

1.3 Why to Read this Book

In this book, different current maintenance activities are discussed, and, while focusing on the particular case of CBM and PM, it also considers future trends and technologies that can support maintenance.

Especially for industrial readers, the book has a section focused on the economic aspects and it introduces some potential methods on how to evaluate the cost benefits of PM and justify the implementation of preventive maintenance.

CBM (and therefore PM), is broken up into processing phases, according to the MIMOSA standard, and later on the processing phases are related to the tools that could be used to fulfil these processing phases.

One further objective of the book is a focus on how the integration between different CBM systems can be done and the benefits of creating an integrated system.

References

Ferri, G., Fumagalli, L., Jantunen, E., Salokangas, R., and Macchi M. (2012). *Simulation tool development to support customer-supplier relationship for cbm services*, In: 11th International Probabilistic Safety Assessment Management Conference (PSAM11), pp. 365–374.

Holmberg, K., Jantunen, E., Adgar, A., Arnaiz, A., Mascolo, J., and Mekid, S. (2010). *E-maintenance.* Springer-Verlag, London.

Jantunen, E., Gorostegi, U., Zurutuza, U., Larringa, F., Albano, M., di Orio, G., Maló, P., and Hegedüs, C. (2017). The way cyber physical systems will revolutionise maintenance. In *30th Conference on Condition Monitoring and Diagnostic Engineering Management (COMADEM)*, July 10–13, 2017, Preston, UK.

Jantunen, E., Gorostegui, U., Zurutuza, U., Albano, M., Ferreira, L. L., Hegedüs, C., and Campos, J. (2018). Remote maintenance support with the aid of cyber-physical systems and cloud technology. *Proceedings of the Institution of Mechanical Engineers, Part I: Journal of Systems and Control Engineering*, Sage Publishing. May 2018.

Jardine, A. K., Lin, D., and Banjevic, D. (2006). A review on machinery diagnostics and prognostics implementing condition-based maintenance. *Mechanical systems and signal processing*, 20(7), 1483–1510.

Mikkonen, H. (2009). *Kuntoon perustuva kunnossapito*, KP-Media Oy, ISBN 978-952-99458-4-9.

Paz, N. M., and Leigh, W. (1994). *Maintenance scheduling: Issues, results and research needs.* International Journal of Operations & Production Management, 14(8), pp. 47–69.

Swedish Standards Institute. (2010). *Maintenance – maintenance terminology – ss-en 13306:2010*.

Wikipedia. https://en.wikipedia.org/wiki/Condition-based_maintenance