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SERENA: Versatile Plug-and-Play Platform Enabling Remote Predictive Maintenance

The increasing complexity of modern engineering systems and manufacturing processes remains a challenge to operating production systems at high levels of reliability. The maintenance of manufacturing assets remains a critical function of every production system since the related cost often reaches 60–70% of its overall lifecycle cost.

Machinery maintenance can cause costly disruptions in the manufacturing process. With predictive analytics, however, repairs and maintenance tasks can be prioritized and allocated to pre-planned outages based on real-time probabilities of various future failures. The strategy of predictive maintenance saves time and money and helps minimize costly production downtimes.

Modern technology in the context of Industry 4.0, including sensors and embedded systems, data analytics and advanced networking, are key enabling technologies towards minimizing downtime of the production system. Empowered by the aforementioned, this study discusses a conceptual framework of a predictive maintenance approach based on equipment condition-based modeling and evaluation, as a step towards reducing breakdowns as well as the overall maintenance costs, through a more efficient time scheduling of the maintenance operations.

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34.1. Introduction

The growing complexity of modern engineering systems and manufacturing processes [CHR 06] is an obstacle to conceptualizing and implementing Intelligent Manufacturing Systems (IMS) and thus keeping these systems operating at high levels of reliability. Additionally, the number of sensors and the amount of data gathered on the factory floor constantly increases [SIP 16], while there are also hidden resources: 85% of data and information are unstructured and 42% of all transactions (sending and receiving information) are still based on paper [THE 15]. This opens the vision of truly connected production processes where all machinery data are accessible, allowing easier maintenance of them in case of unexpected events. SERENA will build upon these needs to save time and money, minimizing the costly production downtimes.

34.2. State of the art and progress beyond

In the literature, several approaches on predictive maintenance platforms have been introduced (e.g. [SPE 17, LIN 17]) but they fail to adequately address the fundamental tension between the flexibility to host many applications, the need of security privacy, data transmission and the user's limited control and management. Condition-based predictive maintenance represent the maintenance approach supported by sensor measurements [COL 14]. The collaboration between IT tools can be enabled and facilitated through mobile technology and communication [MOU 14].

Advantages of cloud computing include the virtualization of resources, parallel processing, security of data and service integration, thus minimizing the cost and restriction for automation and maintenance infrastructure [CHI 13]. An integrated predictive maintenance platform is proposed in [EFT 12], consisting of three main pillars: (1) data acquisition, extraction and analysis; (2) maintenance modeling, knowledge modeling and representation; and (3) advisory capabilities on maintenance planning with emphasis on environmental and energy performance indicators. A semantic framework for predictive maintenance in a cloud environment is introduced in [SCH 17]. The proposed framework is focused on improving decision support in maintenance operations and enabling prediction-as-a-service through data collection, analysis and knowledge sharing. In a similar approach, a condition-based maintenance policy is discussed in [SHI 15] that makes a diagnosis of the asset status using monitored data to predict the asset's abnormalities and executing suitable maintenance actions before serious problems occur. A dynamic predictive maintenance framework is presented in [HOR 13] that deals with decision making and optimization in multi-component systems taking into account the degradation as well as the dependencies of each subcomponent of the multi-component system.

Moving beyond the existing state of the art, the proposed solutions with SERENA cover the requirements for versatility, transferability, remote monitoring and control by: 1) a plug-and-play cloud-based communication platform for managing the data and data processing remotely; 2) an advanced IoT system and smart devices for data collection and monitoring of machinery conditions; 3) artificial intelligent methods for predictive maintenance (data analytics, machine learning) and planning of maintenance and production activities; and 4) AR-based technologies for supporting the human operator for maintenance activities and monitoring of the production machinery status (Figure 34.1).

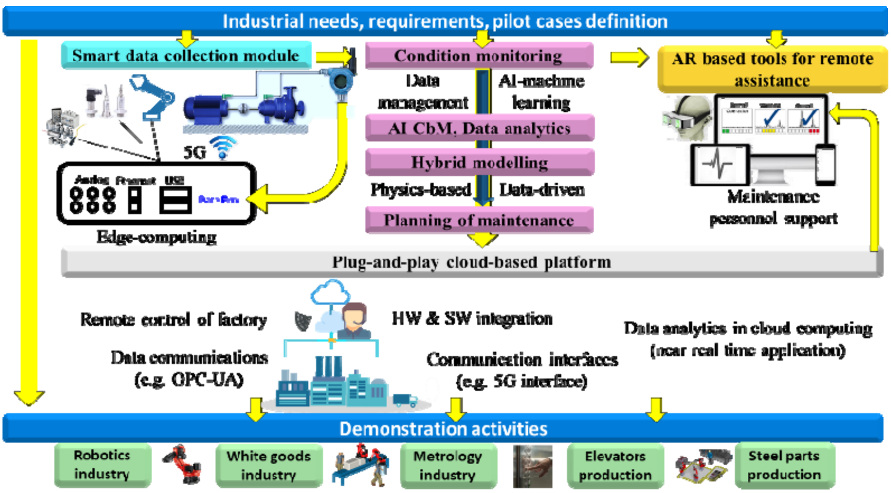

Figure 34.1. *SERENA technologies overview. For a color version of this figure, see www.iste.co.uk/zelm/enterprise.zip*

34.3. Pilot case description

The SERENA solutions, enabling the predictive maintenance concept, will be tested and evaluated in different industrial sectors. The following section will describe the application in the robotics and white goods industry.

34.3.1. *Robotics industry use case*

Currently, the maintenance plan of industrial robots tends to follow mostly the preventive maintenance concept leading to over-maintained machines and thus increased maintenance costs and downtime. The purpose of SERENA is to predict the possible failures of an industrial robot which is executing repeatedly a pick-and-place operation in advance of the actual event. This will be achieved by creating normal operation and failure profiles based on sensor data. Physical models (Figure 34.2) will be created in order to digitally simulate the whole process. The correlation between the two data types, real-world and simulation-driven, will provide a basis for estimating the degradation of the machine as well as its condition.

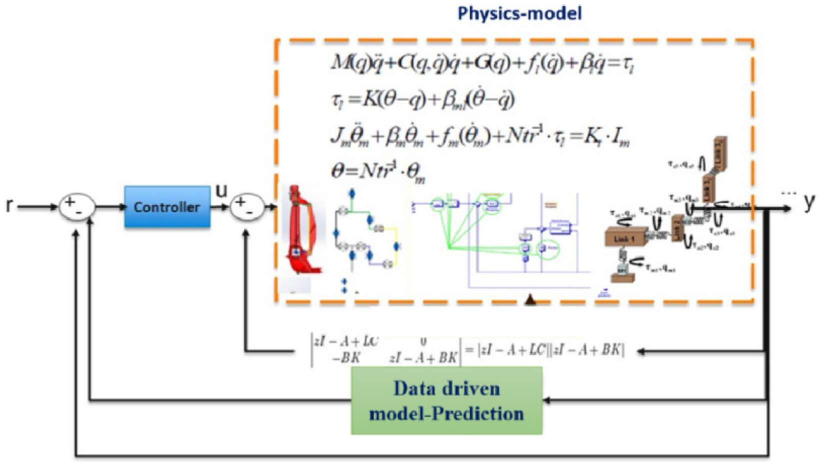

Figure 34.2. *Proposed hybrid approach for predictive maintenance. For a color version of this figure, see www.iste.co.uk/zelm/enterprise.zip*

The use of AR technologies ([MIC 15, MAK 16]) can support the operators during a maintenance activity. By using smart AR glasses the employees' hands remain always free and all information is displayed right in front of them. Through the same software system and with different authorization levels, equipment providers may provide remote assistance to factory personnel, while field operators, running client side applications on mobile devices, will be provided by an overview of the machine and equipment condition, as well as maintenance-related instructions if needed (Figure 34.3).

Experts can directly connect to the ego-perspective of the employees and guide them through maintenance tasks. The operators will be supported with instructions regarding maintenance/repairing activities *in situ*, reducing thus the time and cost for maintenance service from the machine provider. The SERENA solutions provide a first approach to prognostics on specific machines, enabling the condition-based and the predictive maintenance approach.

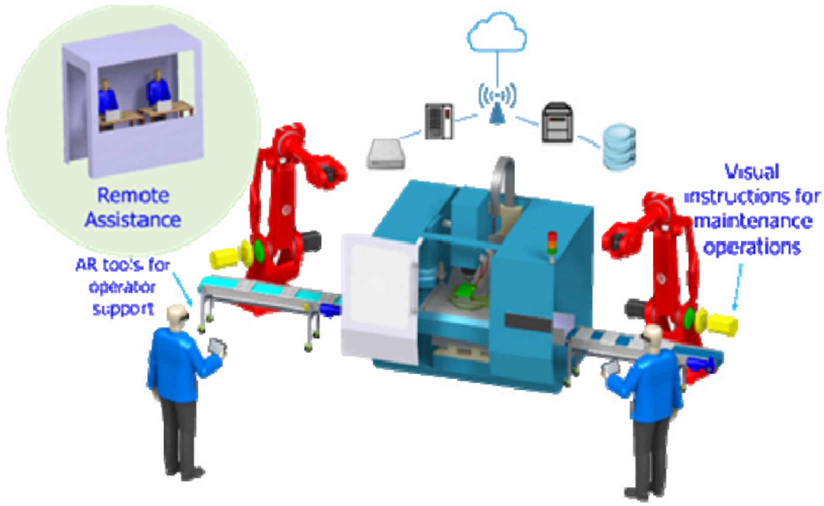

Figure 34.3. *AR-based technologies for remote assistance and human operator support . For a color version of this figure, see www.iste.co.uk/zelm/enterprise.zip*

34.3.2. *White goods industry use case*

The white goods use case will focus on the refrigerator cabinet polyurethane foaming, the core process in fabricating refrigerators and one of the most complex processes in the white goods industry. Computational Intelligence (CI) and Data Mining Technologies (DMT) are required in order to cope with this changing complexity and simplify the decision-making processes with regards to machine maintenance (Figure 34.4).

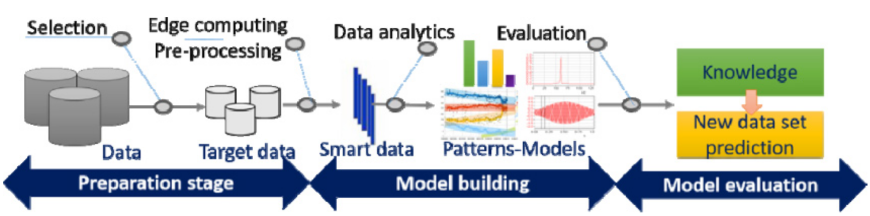

Figure 34.4. *AI condition-based maintenance and planning techniques. For a color version of this figure, see www.iste.co.uk/zelm/enterprise.zip*

Hybrid models consisting of a combination of physics-based and data driven approaches are to be considered in this pilot for increased prediction accuracy. The corrective maintenance activities shall cope with the production activities and thus an intelligent decision making framework is proposed for scheduling and planning the maintenance activities to take place with respect to the existing production orders.

34.4. Acknowledgments

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