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Deliverable 1.1
State-of-Play Analysis on PM Models, Techniques & Platforms

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List of Abbreviations

EPO	European Patent Office
INPADOC	INternational PAtent DOCumentation
IoT	Internet of Things
KPI	Key Performance Indicator
PM	Predictive Maintenance
TRL	Technology Readiness Level
UPTIME	Unified Predictive Maintenance System

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Executive Summary

Task 1.1 State-of-Play Analysis on PM Models, Techniques, and Platforms will set the basis of the UPTIME project by analysing, on the basis of a structured methodology and selected KPIs, several solutions to perform Predictive Maintenance (PM), ranging from reactive maintenance to proactive maintenance, as well as currently available on both commercial and research level platforms implementing PM functionalities. In particular, this Deliverable 1.1 will provide a catalogue with information regarding the state of play in predictive maintenance covering a broad spectrum of platforms that involve several kinds of PM models and techniques. Deliverable 1.1 aims to contribute to the definition of the technical concepts and technological maturity assessment of UPTIME and will be used as input by several tasks in WP1 and WP2.

The analysis on different types of KPIs, scientific literature and platforms has been performed through Desktop Search, Analysis of previous FP7 and H2020 projects (from 2012 onwards). Moreover, a massive Patents Analysis has been conducted using the Derwent Innovation suite[1] tool. It is a comprehensive solution that combines intellectual property, scientific literature, news and business information, integrated with powerful analytics in a robust ICT platform. Considering a temporal range starting from 2001 to nowadays, the number of patents resulting from the database is 175 (ref. INPADOC[2]) patent family. Based on the trend of patent deposition with a temporal range starting from 2001 to nowadays, it identifies a strong growth in the number of patent starting from 2010. China is the country with the most relevant number of deposited patents (141), this is due to a particular attention on this topic paid by several Chinese universities, technology companies and energy sector companies.

According to the results of current analysis, there is also growth towards mass data processing and the IoT (Internet of Things) sector to obtain an overall vision on the industrial process starting from the Predictive Maintenance analysis. This is also in accordance with the System Evolution Theory formulated by G. Altshuller, that the predictive maintenance models techniques and platforms can be collocated in the development phase of the curve of technology evolution.

An excel file with more detailed information on Predictive Maintenance methodologies, models, techniques and platforms is available as an accompanying document to this Deliverable. Both documents are living documents, which will be enriched in the project month 18.

[1] https://clarivate.com/products/derwent-innovation/

[2] INPADOC, which stands for INternational PAtent DOCumentation, is an international patent collection. The database is produced and maintained by the European Patent Office (EPO). It contains patent families and legal status information, and is updated weekly. An INPADOC patent family is a collection of patent applications covering the same or similar technical content.

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1. Introduction

1.1. Objectives of Deliverable 1.1

This task will set the basis of the UPTIME project by analysing, on the basis of a structured methodology, several solutions to perform Predictive Maintenance (PM), ranging from reactive maintenance to proactive maintenance, as well as currently available on both commercial and research level platforms implementing PM functionalities.

In particular this deliverable provides information regarding state of play in predictive maintenance covering a broad spectrum of platforms that involve several kind of PM models and techniques. D1.1 will be used as input by several tasks in WP1 and WP2. In particular Task 1.3 and Task 1.4 will examine the state-of-the-art of how to address the various phases of predictive maintenance standards such as ISO 13374-2:

- existing sensor and acquisition methods-> D1.1 provides input to Task 1.3;
- existing Algorithms/Software for Diagnosis/Prognosis-> D1.1 gives input to Task 1.4;
- existing Algorithms/Software for Decision Support-> D1.1 produces input to Task 1.4.

In addition, Task 2.1 will use the state of play to derive clusters of UPTIME requirements using the identified KPIs. Moreover Task 2.1 will benefit from the work done in this deliverable to confirm and to further address the innovation potential of UPTIME respect the state of the art. The broad spectrum approach used in this deliverable leaves Task 1.3, Task 1.4 and WP2 to extract, tailor or detail key aspects relevant from uptime stakeholder (e.g. on the basis of uptime business case requirements).
The analysis has been performed through Desktop Search, Analysis of previous FP7 and H2020 projects (from 2012 onwards) and with a massive Patents Analysis. The outcomes is the UPTIME catalogue of Models, Technologies and Platform categorized according to the field of applications, highlighting those which are relevant to the three project business cases.
"Predictive maintenance could reduce maintenance costs 10-40%, reduce downtime by 50%, and lower equipment and capital investment by 3-5% by extending machine life" – McKinsey[3]
In general, taking care of maintenance means keeping the workplace, its facilities, its equipment, its machinery and its devices in safe operation, this practice ensures that workplace condition does not deteriorate during the activities. Periodic maintenance can help to prevent sudden and unexpected failures. Industrial maintenance is defined as the set of procedures and actions to be performed to repair faults, prevent them from appearing and restore an asset in a specified state. The maintenance function is, therefore, a necessary function for every type of production process, which is indispensable to ensure the availability of machinery and the safety of people and goods. In addition, proper and efficient maintenance management can be a means of reducing costs and enhancing product quality and thus the competitiveness of the company. For these reasons and with the introduction of Industry 4.0, maintenance today is experiencing a real change in both human and technological organizational level, taking on ever-increasing importance within corporate functions, ranging from simple production index with an unavoidable cost generation to a competitive tool, considered to be a profit centre in all respects. The close connection between quality and maintenance is alike unmistakable. It is, therefore, useful to highlight the importance of the efficiency and good organization of a maintenance service in the production context, especially where the production line is saturated (high production volumes in relation to machine capacity) or where high-quality products and highly efficient processes are required. In the past, quality control was carried out only on the final product, using often destructive statistical methodologies. In retrospect check on final products, based on probabilistic laws, was a costly effort because it required to definitively discard products that were

[3] McKinsey, "The Internet of Things: Mapping the Value Beyond the Hype"

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considered no fitting of quality standards, and it was, however, not useful since it was difficult to apply adaptation measures during the production cycle of the products. It was only at the end of the 1950s that, in order to raise the quality of the productions, it was necessary to provide new tools for the skilled figures involved in quality control, so new production management methods were born ("Just in time", "Computerization and robotization of production cycles "). They were designed to enhance not only the end product but also every stage of the process, proposing the concept that only with maximum commitment at each stage of the cycle it is possible to obtain a top quality service. Today, with the use of new technologies and in particular through informatics and technology deriving by Industry 4.0, maintenance is increasingly moving towards a well-prepared organization, deep in habits and methods. The new direction of maintenance is evidenced by the fact that it is no longer related to the faults. By contrast, maintenance is now integrated into the design from the concept stage, as well as quality. It is, therefore, necessary to foresee the failures so that the consequences can be minimized.

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2. Technology Intelligence Methodology

2.1. Assessment and Definition of Technical Concepts

The Technology Intelligence service is part of RINA Consulting's structured methodology for the identification of patterns of development (technology development rate) and competitors' analysis (level of activity and capability to achieve results). It contributes to the definition of the technical concepts and technological maturity assessment through Desktop Search, Analysis of previous FP7 and H2020 projects (from 2012 onwards) and with a massive Patents Analysis. The methodological backbone of this service is based on the System Evolution Theory formulated by G. Altshuller, a Russian engineer, scientist and patent expert. Altshuller formulated an extensive theory about the creative content of innovations and the possibility to solve technical conflicts inventively, based on the analysis of more than one million patent documents. According to this theory all technologies, starting from the original initial invention, evolve through a multitude of additional developments and improvements, passing through an infancy phase, a maturity period and reaching at the end obsolescence, as shown in the picture below. This means that the development pattern of a specific technology can be predicted by systemic analysis of relevant information (such as the application rate of new patents).

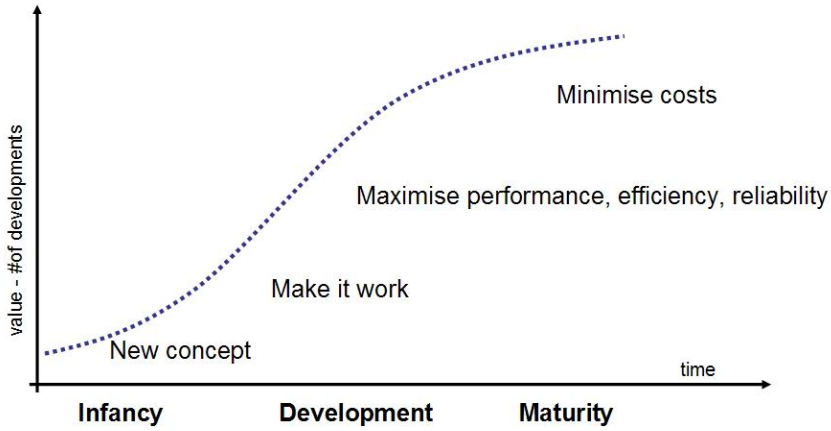


Figure 2.1: Curve of technology evolution

The most interesting technologies for an innovative product conception are those in the infancy stage, enabling the development of a radically new concept. On the contrary, a more mature technology with limited numbers of new applications in a specific industrial sector should be preferred when the aim is to reduce time to market and risks connected to innovation.

To create a "*State-of-Play Analysis on PM Models, Techniques & Platforms*" the analysis has been performed by mining different information sources and databases (eg.: patents database) in order to identify most relevant documents and material focused on:

- KPIs;
- Scientific publication;
- Platforms;
- Patents.

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2.1.1. KPIs Analysis

The state of play presented in the following paragraphs identify the following key performance indicator (KPI) as relevant criteria for the evaluation of the existing Predictive Maintenance Platform. The same KPIs are taken into account also in the requirements and validation phases of the UPTIME maintenance platform becoming input for the WP2 activities.

OVERALL EQUIPMENT EFFECTIVENESS	
NAME: Overall Equipment Effectiveness (OEE)	**OEE=** *(Operational Availability)*(Performance)*(Quality)*
KPI LEVEL: plant or process level	**Operational availability =** $\frac{T_{UP}}{T_{UP}+T_{DOWN}}$
DESCRIPTION: OEE (Overall Equipment Effectiveness) is a standard method for measuring manufacturing productivity of a plant or site. It identifies the percentage of manufacturing time that is truly productive. An OEE score of 100% means you are manufacturing without Defective Parts, as fast as possible, with no Plant Down Time. In the language of OEE that means 100% Quality (no Defective Parts), 100% Performance (as fast as possible), and 100% Availability (no Plant Down Time). Measuring OEE is a manufacturing best practice. By measuring OEE and the underlying losses, you will gain important insights on how to systematically improve your manufacturing process. OEE is the single best metric for identifying losses, benchmarking progress, and improving the productivity of manufacturing equipment (i.e., eliminating waste). Operational Availability value is the most related to the maintenance activities of a plant or process.	**Performance =** $\frac{Parts\ produced * Ideal\ Cycle\ Time}{T_{UP}}$ **Quality =** $\frac{Parts\ produced - Defective\ Parts}{Parts\ produced}$
OBJECTIVE(S): maximize ↑ the Overall Equipment Effectiveness (OEE)	

MAINTENANCE COSTS	
NAME: Maintenance Costs	**n/a**
KPI LEVEL: plant or process level	
DESCRIPTION: sum of all costs related to man-hours for maintenance, spare parts and consumables unit cost, packaging, storage, handling, transportation, training cost for maintainers, disposal cost.	
OBJECTIVE(S): minimize ↓ maintenance costs	

PLANT POWER CONSUMPTION	
NAME: Plant power consumption	**n/a**
KPI LEVEL: plant or process level	
DESCRIPTION: Plant power consumption depends on several prameters, first of all is the Operating time (T_{UP}) of the plant. An other parameters is the plant typology. Many factors are involved in this KPI.	
OBJECTIVE(S): minimize ↓ plant power consumption	

PRODUCTION VOLUME	
NAME: Production volume	**Performance =** $\frac{Parts\ produced * Ideal\ Cycle\ Time}{T_{UP}}$
KPI LEVEL: plant or process level	
DESCRIPTION: Production volume is a function of *Performance* indicator, Production Volume is directly proportional to parts produced.	
OBJECTIVE(S): maximize ↑ Production Volume	

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DEFECTIVE PARTS THRESHOLD	
NAME: Defective Parts threshold	**Quality =** $\frac{Parts\ produced - Defective\ Parts}{Parts\ produced}$
KPI LEVEL: plant or process level	
DESCRIPTION: Defective Parts is a function of *Quality* indicator, a lower value of Defective Parts means an higher value of quality. Defective Parts threshold define if a object is defective or not, the objective is a quantitatively reduction of the parameters that contribute to define a defective part.	
OBJECTIVE(S): minimize ↓ Defective Parts threshold	

MEAN TIME BETWEEN FAILURE	
NAME: Mean Time Between Failure (MTBF)	$MTBF = \frac{1}{\lambda}$
KPI LEVEL: equipment level and plant	
DESCRIPTION: Mean Time Between Failures (MTBF) is the predicted elapsed time between inherent failures of a mechanical system, during normal system operation. MTBF can be calculated as the arithmetic mean (average) time between failures of a system. The term is used in both plant and equipment maintenance contexts. MTBF= 1/λ, where λ is the total failure rate of the equipment	
OBJECTIVE(S): maximize ↑ MTBF	

MEAN TIME BETWEEN CRITICAL FAILURE	
NAME: Mean Time Between Critical Failure (MTBCF)	$MTBCF = \frac{1}{\lambda c}$
KPI LEVEL: equipment level and plant	
DESCRIPTION: Mean Time Between Critical Failures (MTBF) is the predicted elapsed time between inherent failures of a mechanical system, during normal system operation. MTBF can be calculated as the arithmetic mean (average) time between failures of a system. The term is used in both plant and equipment maintenance contexts. A Critical Failure is A failure or combination of failures that prevents an item from performing a specified mission. A critical failure shall be any failure or combination of failures, affecting the equipment hardware, software or both, causing performance degradation under the acceptable threshold, thus resulting in a loss of the required functions and causing the loss of the equipment mission. MTBCF= 1/λc, where λc is the total critical failure rate of the equipment	
OBJECTIVE(S): maximize ↑ MTBCF	

MEAN TIME TO REPAIR	
NAME: Mean Time To Repair (MTTR)	$MTTR = \frac{Sum\ of\ corrective\ maintenance}{Total\ number\ of\ failures}$
KPI LEVEL: equipment level	
DESCRIPTION: Mean Time To Repair (MTTR) is a basic measure of the maintainability of repairable items. It represents the average time required to repair a failed component or device. Expressed mathematically, it is the total corrective maintenance time for failures divided by the total number of corrective maintenance actions for failures during a given period of time. It generally does not include lead time for parts not readily available or other Administrative or Logistic Downtime.	
OBJECTIVE(S): minimize ↓ MTTR	

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2.1.2. Scientific Literature Analysis

To analyse scientific literature was adopted the use of most common online search engines to explore, in an exhaustive way, professional databases, academic journals and social networks. Most interesting publications are present in the following section:

Continuous-time predictive-maintenance scheduling for a deteriorating system	
TITLE: Continuous-time predictive-maintenance scheduling for a deteriorating system	**ABSTRACT:** A predictive-maintenance structure for a gradually deteriorating single-unit system (continuous time/continuous state) is presented in this paper. The proposed decision model enables optimal inspection and replacement decision in order to balance the cost engaged by failure and unavailability on an infinite horizon. Two maintenance decision variables are considered: the preventive replacement threshold and the inspection schedule based on the system state. In order to assess the performance of the proposed maintenance structure, a mathematical model for the maintained system cost is developed using regenerative and semi-regenerative processes theory. Numerical experiments show that the s-expected maintenance cost rate on an infinite horizon can be minimized by a joint optimization of the replacement threshold and the a periodic inspection times. The proposed maintenance structure performs better than classical preventive maintenance policies which can be treated as particular cases. Using the proposed maintenance structure, a well-adapted strategy can automatically be selected for the maintenance decision-maker depending on the characteristics of the wear process and on the different unit costs. Even limit cases can be reached: for example, in the case of expensive inspection and costly preventive replacement, the optimal policy becomes close to a systematic periodic replacement policy. Most of the classical maintenance strategies (periodic inspection/replacement policy, systematic periodic replacement, corrective policy) can be emulated by adopting some specific inspection scheduling rules and replacement thresholds. In a more general way, the proposed maintenance structure shows its adaptability to different possible characteristics of the maintained single-unit system
AUTHOR(S): A. Grall, L. Dieulle, C. Berenguer and M. Roussignol	
AFFILIATION: Lab. de Modelization et Surete des Systemes, Univ. de Technologie de Troyes, France	
PUBBLICATION YEAR: 2002	
JOURNAL: IEEE Transactions on Reliability, vol. 51, no. 2, pp. 141-150, Jun 2002.	

A rapid control prototyping platform methodology for decentralized automation	
TITLE: A rapid control prototyping platform methodology for decentralized automation	**ABSTRACT:** Today's industrial requirements regarding the ability of embedded devices used for decentralized automation are increasing. Industrial providers of automation equipment strive to make their products and thus, industrial plants, smarter to raise efficiency. This evolution is based on new technologies like machine learning, predictive maintenance, sensor fusion and advanced process controls. These techniques require performance and energy efficient hardware platforms supporting a fast execution of computational intensive algorithms in compliance with real-time constraints. Therefore, to achieve these targets in a cost-efficient manner, the sharing of hardware resources to implement advanced process controls or machine learning algorithms is beneficial. Further, if different institutions integrating intellectual property (IP) into a single platform a certain degree of isolation is mandatory to protect their IP against theft or manipulation. In this paper, we propose a rapid control prototyping platform supporting the sharing of resources in an isolated manner to evaluate new control or monitoring strategies on a single platform with the help of Linux Containers for process isolation, MQTT for interprocess communication, OPC UA for vertical integration and partial bitstreams.
AUTHOR(S): Florian Kästner, Benedikt Janßen, Sebastian Schwanewilms.	
AFFILIATION: Ruhr-University Bochum, Germany	
PUBBLICATION YEAR: 2017	
JOURNAL: IEEE Xplore: 01 December 2017	

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Cloud architecture for industrial image processing: Platform for realtime inline quality assurance	
TITLE: Cloud architecture for industrial image processing: Platform for realtime inline quality assurance	**ABSTRACT:** Cloud computing offers the opportunity to minimize the evaluation time of complex algorithms - e.g. needed for computational imaging - by horizontal scaling of the available computing resources. By this way, new image analyzing algorithms can be employed in weak real-time conditions, like inline quality analysis in production with time stamps in the order of several tens of seconds. The cloud offers a platform to merge sensor data of all production processes to analyze quality data comprehensively, e.g. for methods like predictive maintenance. Typically, cloud environments are applied for the Internet of things (IoT) or Big Data analysis. But IoT-applications usually generate very small data packages (like sensor values with a size much less than 1 megabyte), while BigData applications deal with very high data volume (terra- or petabyte). Image processing requires an environment, which is optimized for medium size data streaming, composed of images with a size in the lower megabyte range. In this paper, a sensor-to-cloud architecture as a platform for image processing is described. This approach is upward compatible, because it is not necessary to change the sensor hardware, e.g. if algorithms with considerable higher computing complexity are desired (like for a smart camera), so algorithms can be exchanged in the cloud without interrupting the production process. The case study investigated in this paper is based on inline analysis of the surface quality of metal sheets after forming, i.e. the edge of the door of a car. This process might cause surface blemish like orange peel and cracks. Quality control is necessary, before car components are varnished.
AUTHOR(S): Dirk Jacobsen, Peter Ott.	
AFFILIATION: Heilbronn University, Germany	
PUBBLICATION YEAR: 2017	
JOURNAL: IEEE Xplore: 13 November 2017	

Concept of predictive maintenance of production systems in accordance with industry 4.0	
TITLE: Concept of predictive maintenance of production systems in accordance with industry 4.0	**ABSTRACT:** In the proposed paper, we described the approach to build Hadoop based knowledge discovery platform. The proposal focuses on predictive maintenance of production systems, including manufacturing machines and tools, to increase the production process quality. The proposal utilises production data storage, built on Hadoop framework and NoSQL systems, integrated into traditional data warehouse discovery platform, preserving the well proven and robust data warehouse decision support and analytic tools. The initial proof of concept case study is included in the proposed paper.
AUTHOR(S): Lukas Spendla, Michal Kebisek, Pavol Tanuska, Lukas Hrcka.	
AFFILIATION: Slovak University of Technology, Trnava, Slovakia	
PUBBLICATION YEAR: 2017	
JOURNAL: IEEE Xplore: 20 March 2017	

Development of Advanced Manufacturing Cloud of Things (AMCoT)—A Smart Manufacturing Platform	
TITLE: Development of Advanced Manufacturing Cloud of Things (AMCoT)—A Smart Manufacturing Platform	**ABSTRACT:** As semiconductor manufacturing processes are becoming more and more sophisticated, how to maintain their feasible production yield becomes an important issue. Also, how to build a smart manufacturing platform that can facilitate realizing smart factories is essential and desirable for current manufacturing industries. Aimed at addressing the above-mentioned two issues, in this letter, a five-stage approach for enhancing and assuring yield is proposed. Also, a smart manufacturing platform- Advanced Manufacturing Cloud of Things (AMCoT) based on Internet of Things, cloud computing, big data analytics, cyber-physical systems, and prediction technologies is designed and implemented to realize the proposed five-stage approach of yield enhancement and assurance. Finally, AMCoT is applied to a bumping process of a semiconductor company in Taiwan to conduct industrial case studies. Testing results demonstrate that AMCoT possesses capabilities of conducting total inspection in production, providing prognosis, and predictive maintenance on equipment, finding the root cause of yield loss, and storing and handling big production data, which as a whole is promising to achieve the goal of zero defects.
AUTHOR(S): Yu-Chuan Lin ; Min-Hsiung Hung ; Hsien-Cheng Huang ; Chao-Chun Chen ; Haw-Ching Yang ; Yao-Sheng Hsieh ; Fan-Tien Cheng	
AFFILIATION: University Politehnica of Bucharest, Romania	
PUBBLICATION YEAR: 2017	
JOURNAL: Y. C. Lin et al., "Development of Advanced Manufacturing Cloud of Things (AMCoT)—A Smart Manufacturing Platform," in IEEE Robotics and Automation Letters, vol. 2, no. 3, pp. 1809-1816, July 2017.	

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Integrating maintenance within the production process through a flexible E-maintenance platform	
TITLE: Integrating maintenance within the production process through a flexible E-maintenance platform	**ABSTRACT:** The paper aims at discussing the design choices of a flexible E-maintenance platform. The platform is built based on the combined use of web services and statistical analysis, in order to obtain a tool-box featuring high usability for an agile integration of maintenance activities within the production process. The flexibility is demonstrated through the implementation of Condition Based Maintenance in a manufacturing case study. This provides a proof of the potential improvement that can be achieved for the integration of maintenance management within production management, leveraging on a strategy of condition based operations of the shop floor.
AUTHOR(S): Luca Fumagalli, Marco Macchi.	
AFFILIATION: Department of Management, Economics and Industrial Engineering, Politecnico di Milano, Italy	
PUBBLICATION YEAR: 2015	
JOURNAL: Luca Fumagalli, Marco Macchi, Integrating maintenance within the production process through a flexible E-maintenance platform, IFAC-PapersOnLine, Volume 48, Issue 3, 2015, Pages 1457-1462	

On a Predictive Maintenance Platform for Production Systems	
TITLE: On a Predictive Maintenance Platform for Production Systems	**ABSTRACT:** Maintenance and support may account for as much as 60 to 75% of the total lifecycle cost of a manufacturing system. This paper presents a review on the predictive maintenance approaches, methods and tools in manufacturing systems and proposes an integrated predictive maintenance platform. This platform consists of three pillars, namely data acquisition and analysis, knowledge management, and a sustainability maintenance dashboard. The first pillar is responsible for data extraction and processing, the second one focuses on the maintenance knowledge modeling and representation and the third pillar provides advisory capabilities on maintenance planning with special emphasis given to environmental and energy performance indicators.
AUTHOR(S): K.Efthymiou, N.Papakostas, D.Mourtzis, G.Chryssolouris	
AFFILIATION: Laboratory for Manufacturing Systems & Automation, Department of Mechanical Engineering & Aeronautics, University of Patras, Greece	
PUBBLICATION YEAR: 2012	
JOURNAL: K. Efthymiou, N. Papakostas, D. Mourtzis, G. Chryssolouris, On a Predictive Maintenance Platform for Production Systems, Procedia CIRP, Volume 3, 2012, Pages 221-226	

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2.1.3. Platforms Analysis

Platforms Developed in EU R&D Projects

To obtain a vision on platforms technologically advanced focused on Predictive Maintenance, a Desktop Search and an Analysis of previous FP7 and H2020 projects (from 2012 onwards) was performed, in the following section is present a summary of the most relevant solution:

NAME: Dynamite (Dynamic Decisions in Maintenance)	
PRODUCER: European Consortium	
CATEGORY: Platform	
REFERENCES: Alexandre Voisin, Eric Levrat, Pierre Cocheteux, Benoît Iung. Generic prognosis model for proactive maintenance decision support: application to pre-industrial e-maintenance test bed. Journal of Intelligent Manufacturing, Springer Verlag (Germany), 2009, 21 (2), pp.177-193.	
KEYWORDS: machines monitoring , predictive maintenance, control.	**BUSINESS SECTOR AND EVALUATION:** Advanced e-maintenance solution for industry and transportation.
KEY PERFORMANCE INDICATOR (if possible): **Maintenance Costs**	**PRICE:** n/a

DESCRIPTION: The EU-funded project 'Dynamic decisions in maintenance' (Dynamite) developed a novel high-tech maintenance approach based on advanced communications and sensor technology, complete with ingenious diagnostic and prognostic features.

The project worked on a prototype for a global mobile monitoring e-maintenance infrastructure, which involved developing appropriate devices and software. These included wireless telemetry and online instrumentation, as well as smart tags that document history, identity and communications.

Dynamite worked on creating a low-cost mobile wireless device to enhance access and reporting through e-maintenance. It also worked on an online oil sensor combining particle counting, distribution and composition in a single instrument.

The project successfully developed DynaWeb, an e-maintenance solution based on scenario analysis of future industrial needs and trends for plant operators, manufacturers, transportation companies and more. The system includes 28 integrated hardware and software components that provide flexible online monitoring and maintenance data at many levels, communicating with handheld mobile computers to facilitate the task. It also includes training services and decision support based on technical and economic considerations.

DynaWeb was tested in real-life applications on industrial installations including a milling machine, machining tools, foundry hydraulics, maritime lubrication system and automatic stamping machine. It demonstrated its strength as a viable set of tools and methods for cost-effective maintenance technologies that encourage profitability and competitiveness.

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NAME: SNCF and IBM	
PRODUCER: IBM	
CATEGORY: Platform	
REFERENCES: https://www.ibm.com/blogs/internet-of-things/sncf-iot-french-railways/	
KEYWORDS: data analysis, IoT, predictive manintenance	**BUSINESS SECTOR AND EVALUATION:** French Railway infrastructure
KEY PERFORMANCE INDICATOR (if possible): Operational Availability, Maintenance Costs, Mean Time To Repair	**PRICE:** n/a

DESCRIPTION: SNCF (French National Railway) turned to IBM Watson IoT to help keep things on track, deploying thousands of sensors on trains and tracks which are securely sending tens of thousands of data points in the cloud, all in real-time. By analyzing the data from these sensors, engineers and other personnel can connect to running trains in real time, allowing SNCF to anticipate when a specific item, such as a faulty signal component, is in need of repair. By predicting when maintenance is needed, SNCF can prevent trains from being taken out of service while avoiding more costly repairs. SNCF estimates that this train and track maintenance approach could reduce costs while significantly improving the reliability of its signals and trains. In addition, with this up-the-second insight, maintenance teams will also constantly be updated on the state of the rail infrastructure and when needed, can provide early warning to expert teams in charge, when there is risk of dysfunction.

Critical to this effort is SNCF's use of IBM Cloud-based Watson IoT Platform capabilities, which connect its entire rail network made up of thousands of components, the rails and stations. With Watson IoT, the railway company is successfully minimizing delays, ensuring passenger safety and delivering a superior on-train experience for commuters. At the heart of this effort are thousands of sensors which SNCF is deploying on its trains, covering more 30,000 kilometres of track, 15,000 trains and 3,000 stations. Each of these sensors immediately and securely will send tens of thousands of data points to the IBM Watson IoT Platform on IBM Cloud where the data is analyzed in real-time.

Using IoT technology, engineers can connect to running trains in real time, enabling SNCF to monitor components and remotely manage work carried out on each individual potential train or rail issue. For example, SNCF can remotely monitor train doors for potential failures, air conditioning, windshield water levels and oil temperatures. By connecting to running trains, engineers and other personnel can anticipate when specific issues need to be addressed. Using predictive analytics, SNCF has been able to successfully prevent trains from being taken out of service while avoiding more costly repairs. One key area of focus is the temperature of rails. Excessive heat can cause long term maintenance problems that affect the safety of trains, especially those running at high speed.

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NAME: SUPREME (SUstainable PREdictive Maintenance for manufacturing Equipment)	
PRODUCER: European Consortium	
CATEGORY: Platform	
REFERENCES: SUPREME PROJECT COORDINATOR Sophie SIEG-ZIEBA (CETIM – FRANCE) https://cordis.europa.eu/result/rcn/181757_en.html	
KEYWORDS: predictive maintenance, real time, data analysis	**BUSINESS SECTOR AND EVALUATION:** Advanced e-maintenance solution for manufacturing equipment
KEY PERFORMANCE INDICATOR (if possible): Operational Availability, Maintenance Costs, Plant Power Consumption	**PRICE:** n/a

DESCRIPTION: Productivity improvements have major impact on EU economy and competitiveness. Industrial maintenance contributes largely to this competitiveness through reliability and availability of production equipment. The EU market of industrial maintenance can be estimated at 32 Bn€/year, in which outsourced maintenance represents 1/3. In continuous production industries (energy, chemical, food, cement or paper sectors) the ratio "maintenance costs/added value product" is even higher than 25%. In these industries, default component or process failure stop the whole production, therefore predictive maintenance is a critical issue.
In addition, a lot of EU industries are facing a new challenge with the rising cost of energy, which is impacting dramatically the production costs and so the competitiveness.
In this context, SUPREME project has developed new tools to adapt dynamically the maintenance and operation strategies to the current condition of the critical components in production equipment.
It also proposes an integrated approach to optimize the production process and its energy consumption.
To reach these objectives, the SUPREME project has :
- developed and used most advanced signal and data processing dedicated to predictive maintenance and energy consumption reduction,
- enhanced and developed new maintenance tools,
- implemented all these tools in an industrial demonstrator (paper industry),

SUPREME's main challenging R&D activities developed were:
-Innovative reference models for residual life prediction and optimal predictive maintenance of deteriorating system,
-Embedded advanced signal acquisition and features extractions for varying operating conditions machines,
-Real time data fusion (vibrations, acoustic emission, motor current, torque,...),
-Off line data mining and self-learning failure mode pattern,
-Automated loop for monitoring optimal machine stabilization,
-Dynamically updated condition monitoring software module,
-Specific dissemination tools including e-learning modules.
The project impact is the proof of predictive maintenance efficiency, reduction of down-time and energy consumption in manufacturing industry, demonstrated in a coated paper mill.
The SUPREME project ("SUstainable PREdictive Maintenance for manufacturing Equipment") is funded by the European Commission in FP7 Programme, under the Factories of the Future PPP.
Started in September 2012, the SUPREME consortium integrates key technical players on maintenance added value chain, gathering technology and service providing SMEs.
The consortium gathers ten partners. Three of them are SMEs with RTD capacities (EC Systems, Loy & Hutz and Optimitive), to make possible the development of three modules which will be integrated to set-up the complete approach (ECMS (Embedded Condition Monitoring System), Reliability and Maintainability Module and Intelligent Control Module). The research work is conducted by teams from Grenoble-INP, CETIM, Fraunhofer IPA and CVUT. The application case in the paper industry is driven by Orloga (SME) and Condat (Lecta group). While the experience of Cofely Endel in maintenance will ensure that the new developments are applicable for various industrial fields.

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NAME: POWER-OM (Power consumption driven Reliability, Operation and Maintenance optimisation)	Power-OM
PRODUCER: European Consortium	
CATEGORY: Platform	
REFERENCES: Power-OM PROJECT COORDINATOR Aitor Alzaga aitor.alzaga@tekniker.es https://cordis.europa.eu/result/rcn/175588_en.html	
KEYWORDS: predictive maintenance, real time, data analysis	**BUSINESS SECTOR AND EVALUATION:** Advanced e-maintenance solution for industrial sector
KEY PERFORMANCE INDICATOR (if possible): Plant Energy Consumption, Defective Parts Threshold, Operational Availability	**PRICE:** n/a

DESCRIPTION: European manufacturers of machine tools are positioned in the manufacture of high value-added products. The fact that customers buy machines with high added value means that these machines are used in critical processes and therefore expect machines free of failures. In these machines, spindle faults are responsible for the most common and cost-intensive downtimes in machine-tools.

The normal strategy to keep these production systems in good conditions is to apply preventive maintenance practices and complement it with a supportive workforce "reactive" in the case of clearly detected malfunctions. This impact on quality, cost and in general, productivity. Added to this, the uncertainty of machine reliability at any given time, also impacts on product/production delivery times.

The use of intelligent predictive technologies could contribute to improve the situation, but these techniques are not widely used in the production environment. Sensors and other monitoring techniques required for the production environment are not so standard and require costly implementations.

Project has research in the development of those mechanisms that can make possible the implementation of a pro-active maintenance strategy:

- Machine tool health assessment using the Electric Signature Analysis technique. This has been applied to the most critical components (spindle and linear axis) that are responsible of more than 80% of the idle time.
- Machine working condition monitoring
- The collection and analysis of data at the fleet level

The technology developed is easy to implement and little intrusive, allowing the machine tool manufacturer:

- Be more pro-active regarding potential problems that the client may have,
- Conduct a faster and more accurate diagnosis,
- Provide recommendations for the future; for example, the spindle head which suits better the customer type of work.

This is something could be offered by the machine tool manufacturer as a standard feature. The efforts made by the manufacturer would be rewarded for its ability to anticipate problems and respond to customers more efficiently and orderly. Moreover, the machine manufacturer would have valuable information regarding the behaviour of the machine in relation to the use that would, among other things, future product enhancements.

The results can be categorized in two groups:

- Components that can be embedded in the machine as data loggers to save working conditions and to implement the finger print concept based on current signal capture and its analysis.
- e-Maintenance platform to aggregate the information coming from the fleet of machines. This includes the knowledge model to facilitate heterogeneous knowledge (i.e. data, information, results) retrieval and sharing on the basis of the monitored units composing the fleet. Final objective is to make periodic assessment of performance indices (health, energy consumption and other KPIs). The system generates also pro-active alarm when a drift in the machine tool performance or some component degradation is detected. The knowledge/data found in the fleet help also in the predictive diagnostic of the fault.

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NAME: IMAIN (A Novel Decision Support System for Intelligent Maintenance)	
PRODUCER: European Consortium	
CATEGORY: Platform	
REFERENCES: www.imain-project.eu https://cordis.europa.eu/result/rcn/157815_en.html	
KEYWORDS: predictive maintenance, real time, data analysis	**BUSINESS SECTOR AND EVALUATION:** Advanced e-maintenance solution for industrial sector
KEY PERFORMANCE INDICATOR (if possible): MTBF, MTBCF, Power Consumption	**PRICE:** n/a

DESCRIPTION: iMain is a European level research project aiming to develop a novel decision support system for predictive maintenance. To that end, a multi-layer solution integrating embedded information devices and artificial intelligence techniques for knowledge extraction and novel reliability & maintainability practices will be developed. The resulting solution will provide extended capabilities compared to those achievable with current state-of-the-art maintenance practices, increasing system lifetime of the production equipment at least 30%, energy efficiency at least 20%, availability of whole process at least 30% while decreasing maintenance costs at least 40%.
The iMain project is strongly committed to deployment issues, including innovation and implementation actions focused on value chains and bridging the gap from research to market. iMain acknowledges the significance of exploitation, puts emphasis on the commercialisation of results, also taking into account the needs of post-project monitoring of the commercialisation process. Monitoring progress after the project end will reveal the results of the funding received and evaluate the effectiveness of the innovation mechanism developed.
As a step towards the Horizon2020 strategy, the iMain project will thus make a contribution in terms of R&D investment, employment and resource efficiency, aiming to assist EU manufacturers, particularly SMEs, to adapt to global competitive pressures by increasing the technological base of EU manufacturing through the development and integration of the enabling technologies of the future, specifically engineering technologies for novel predictive maintenance solutions.

Project Results:
In the finalized work package 1, first the production equipment has been analyzed regarding critical components, which are relevant for maintenance, and a condition and energy monitoring strategy has been developed. To increase the efficiency of the monitoring solution and to minimize the number of necessary real sensors, it will be supported by the development and implementation of virtual sensors. Virtual sensors can be considered as one main novelty of the project. For this and to support monitoring planning, varying simulation models has been developed. These models allow the virtual analysis of mechanical strains and stresses as well as the estimation of influences on the energy consumption. Based on the FE models and in combination with strain measurements on both demonstration presses, the parameters for the virtual sensors have been derived.
The embedded condition and energy monitoring system (ECEM) as the main base for maintenance has been developed in WP2. It allows data acquisition and pre-processing in realtime on the ECEM-DA module and comprehensive service life prediction operations on the ECEM PC. The architecture for the acquisition hardware has been defined as a combination of a specialized embedded device with realtime capability and a supporting PC based system for configuration, additional processing and storage. Prototypes for both components have been delivered. The ECEM-DA is actually installed at both presses and is basically connected to the cloud. In the second period this system will be extended to the ECEM PC and optimized.
In work package 3 the theoretical works for the service life prediction system (lifPRED) and an offline prediction system (lifPRED mirror) is in progress that will finally run on the ECEM PC. The development of the needed processing environment is finished and is partly connected to the e-maintenance cloud.
Work package 4 deals with the development of the e-maintenance cloud. A special architecture has been developed and the hard- and software has been specified. The software architecture is comprised from various software services (sql service, virtual desktop service, software development service, alarm service, SEARCH-database service, database management service, post processing service, dashboard service) and describes their dependencies and interaction within the eMaintenance cloud.
Finally, several dissemination activities like (website, publications, flyers, posters, clustering activities) have been done and will be continued in the second period.

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Commercial Platforms

Tables below summarise the potential commercial competitors of the UPTIME E-Maintenance Platform. The list will be finalised and enriched in WP8 "Market Research Report".

NAME: IoT Predictive Maintenance	
PRODUCER: Software AG (Germany)	
CATEGORY: Data Analytics platform	
REFERENCES: http://www1.softwareag.com/corporate/solutio	
KEYWORDS: platform, data analysis, predictive maintenance	**BUSINESS SECTOR AND EVALUATION:**
KEY PERFORMANCE INDICATOR (if possible): n/a	**LICENSE:** Payment
DESCRIPTION: Preventative maintenance is expensive, downtime caused by equipment failures is even more costly but machine maintenance has been performed this way for years. Even if you can predict failures, dynamic technician scheduling associated with equipment maintenance management requires insight into real-time held inventory, technician location and estimated service completion time. Software AG's solution for predictive maintenance leverages the Internet of Things (IoT) by continuously analyzing real-time equipment sensor data via machine monitoring to understand when maintenance will be required. Technician locations are coupled with replacement/repair equipment available and job completion time to identify the best technician available to perform the needed service during a scheduled downtime.	

NAME: Manufacturing Analytics and Predictive Maintenance	
PRODUCER: BOSCH (Germany)	
CATEGORY: Data Analytics platform	
REFERENCES: https://www.bosch-si.com/manufacturing/solutions/maintenance/	
KEYWORDS: platform, data analysis, predictive maintenance	**BUSINESS SECTOR AND EVALUATION:**
KEY PERFORMANCE INDICATOR (if possible): n/a	**LICENSE:** Payment
DESCRIPTION: Thanks to suitable machine-learning algorithms, Data Analytics can use process data to help identify the optimum time for maintenance. Predictive maintenance thus provides several benefits -Less downtime and optimum maintenance intervals increase output. -Product quality is ensured. Detecting machine breakdowns early on improves the efficiency of maintenance work and opens up entirely new opportunities: -Create new market opportunities by offering your customers additional services regarding maintenance and resource optimization; -Optimal scheduling of maintenance measures reduces costs, boosts customer satisfaction, and distinguishes your portfolio from those of competitors; -Intelligent Industry 4.0 solutions – such as Manufacturing Analytics and the Production Performance Manager – facilitate integrated, trouble-free processes throughout a company and for the duration of the maintenance process; -More predictable scheduling of maintenance measures helps avoid the expenses of unscheduled production downtime and cuts resource costs.	

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NAME: Azure Machine Learning Studio	
PRODUCER: Microsoft Corporation (USA)	
CATEGORY: Cloud platform for predictive analysis	
REFERENCES: studio.azureml.net	
KEYWORDS: machine learning, cloud, predictive maintenance	**BUSINESS SECTOR AND EVALUATION:**
KEY PERFORMANCE INDICATOR (if possible): n/a	**LICENSE:** Payment

DESCRIPTION: Azure is a comprehensive set of cloud services that developers and IT professionals use to build, deploy, and manage applications through our global network of datacenters. Integrated tools, DevOps, and a marketplace support you in efficiently building anything from simple mobile apps to internet-scale solutions.



NAME: IBM Bluemix	
PRODUCER: IBM (USA)	
CATEGORY: cloud platform and services	
REFERENCES:	
KEYWORDS: machine learning, cloud, predictive maintenance	**BUSINESS SECTOR AND EVALUATION:**
KEY PERFORMANCE INDICATOR (if possible): n/a	**LICENSE:** Payment

DESCRIPTION: Bluemix is an implementation of IBM's Open Cloud Architecture, based on Cloud Foundry (open-source platform), that enables you to rapidly create, deploy, and manage your cloud applications. Because Bluemix is based on Cloud Foundry, you can tap into a growing ecosystem of runtime frameworks and services. In addition to providing additional frameworks and services, Bluemix provides a dashboard for you to create, view, and manage your applications and services as well as monitor your application's resource usage. The Bluemix dashboard also provides the ability to manage organizations, spaces, and user access.
Bluemix provides access to a wide variety of services that can be incorporated into an application. Some of these services are delivered through Cloud Foundry. Others are delivered from IBM and third party vendors. New and enhanced services are added to the catalog often. To see the current list of runtimes and services, and their status go to the Bluemix catalog.
Some of the commonly used runtimes are: Node.js, PHP, Python, Ruby.
Some of the Bluemix services available from the expanding catalog include: BigInsights for Hadoop, Business Rules, Cloudant NoSQL DB, Data Cache, DevOps Auto-Scaling, Delivery Pipeline in the IBM Bluemix Continuous Delivery service, Embeddable Reporting, Geospatial Analytics, Internet of Things, Mobile Push Notifications, MongoDB, MQ Light, Secure Gateway, Sendgrid, Session Cache, Single Sign-On, SQL Database, Watson Alchemy API, Watson Language Translation, Watson Personality Insights.

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NAME: IBM Watson	
PRODUCER: IBM (USA)	
CATEGORY: API on IBM cloud	
REFERENCES:	
KEYWORDS: machine learning, cloud, predictive maintenance, API	**BUSINESS SECTOR AND EVALUATION:**
KEY PERFORMANCE INDICATOR (if possible): n/a	**LICENSE:** Payment after 30-day free trial
DESCRIPTION: IBM Watson is part of one of the services available on the IBM Bluemix platform. Watson's APIs allow you to create cognitive products. It offers different solutions: - Conversation: to build virtual agents able to converse using natural language (chatbot) - Discovery: to build cognitive applications and then to extract useful contents from raw data - Natural language classifier and understanding: to analyse, interpret and classify natural language. From these analyses also understand, for example, the characteristics of a person based on the his way of writing or speaking (personality insights) - Retrieve and rank: extract important information from document collections through the use of machine learning techniques - Conversion of human voice into written text and vice versa - Image recognition	

NAME: IBM Maximo	
PRODUCER: IBM (USA)	
CATEGORY: Asset management	
REFERENCES: https://www.ibm.com/us-en/marketplace/maximo?lnk=STW_US_MAST_L1_TL&lnk2=learn_EntAssetMgmt	
KEYWORDS: assets management, service management, deplyement, predictive maintenance	**BUSINESS SECTOR AND EVALUATION:**
KEY PERFORMANCE INDICATOR (if possible): n/a	**LICENSE:** Payment
DESCRIPTION: Maximo, when combined with the power of IoT data from people, sensors and devices, can provide warning signals from assets—reducing unplanned downtime and increasing operational efficiency. With this data, it also enables near real-time visibility into asset usage across multiple sites, extends the useful life of equipment, improves return on assets and defers new purchases. Key features of Maximo: - Asset management - Procurement and materials management - Service management - Work management - Contract management - Additional features - Flexible deployment options	

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NAME: Oracle Data Integrator	
PRODUCER: Oracle Corporation (USA)	
CATEGORY: Data management platform	
REFERENCES: http://www.oracle.com/technetwork/middleware/data-integrator/overview/index.html	
KEYWORDS: platform, data integrator, data management	**BUSINESS SECTOR AND EVALUATION:**
KEY PERFORMANCE INDICATOR (if possible): n/a	**LICENSE:** Payment

DESCRIPTION: Oracle's PeopleSoft Maintenance Management is a fully integrated solution for the maintenance of infrastructure, plant, and equipment—enabling organizations to streamline operations, facilitate compliance, and eliminate costly, inadequate custom integrations to third-party systems. Through out-of-the-box integration with other PeopleSoft applications such as Project Costing, Asset Management, Purchasing, and Inventory, PeopleSoft Maintenance Management enables you to prioritize assets and ensure the right level of investment to meet utilization and financial goals.
PeopleSoft IT Asset Management offers a comprehensive solution for reducing hardware and software costs, controlling service expenses, and automating software and regulatory compliance.

- Gain greater insight into IT asset performance by implementing the best practice of perpetual auto-discovery, which takes inventory of IT assets, including software, servers, client devices, and mobile devices that connect to your network.
- Streamline IT asset lifecycle by comparing inventory-based discoveries against financial records in order to highlight exceptions for appropriate action.
- Ensure IT and corporate compliance with visibility into key information, including the number of software licenses installed versus licenses in inventory, and authorized and unauthorized installations.
- Perform full lifecycle management—including planning, requisition, acquisition, discovery and reconciliation of IT assets—by leveraging out-of-the-box integration with Oracle's PeopleSoft Financial Management, Human Capital Management, and Supply Chain Management applications.

NAME: APM Strategy	
PRODUCER: General Electric (USA)	
CATEGORY: Data Analytics platform	
REFERENCES: https://www.ge.com/digital/products/asset-	
KEYWORDS: platform, data analysis, predictive maintenance, assets	**BUSINESS SECTOR AND EVALUATION:**
KEY PERFORMANCE INDICATOR (if possible): n/a	**LICENSE:** Payment

DESCRIPTION: APM Strategy, a Predix APM solution, provides a common methodology to develop and manage asset strategies by using a risk-based approach to conduct analysis of individual assets, a group of assets, or an asset system. By balancing risk, production goals, and resource investment, APM Strategy allows asset-intensive organizations to focus costs on the most critical assets—reducing maintenance and inventory costs, increasing availability and reliability, and moving away from reactive maintenance practices to a proactive approach.

APM Strategy can perfom this task:
Analyze: Identify potential failures of individual assets and entire systems, thus reducing unplanned downtime
Determine: Perform optimal maintenance, inspection, or redesign activities, while most effectively balancing risk and costs
Optimize: Implement strategies based on failure modes and effects analysis (FMEA), predictive analytics, health indicators, policies, and reliability analyses
Develop: Create strategies in various work management and control systems for complete integration and improved productivity

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NAME: @ptitude Monitoring Suite	
PRODUCER: SKF (SWE)	
CATEGORY: Data Analytics platform	
REFERENCES: http://www.skf.com/group/products/condition-	
KEYWORDS: platform, data analysis, predictive maintenance, Condition monitoring	**BUSINESS SECTOR AND EVALUATION:**
KEY PERFORMANCE INDICATOR (if possible): n/a	**LICENSE:** Payment

DESCRIPTION: The SKF @ptitude Monitoring Suite forms the basis for a completely integrated approach to condition monitoring, permitting fast, efficient and reliable storage, manipulation and retrieval of large amounts of complex machine and plant information.
SKF @ptitude Monitoring Suite components:
- SKF @ptitude Analyst
SKF @ptitude Analyst provides fast, efficient and reliable storage, analysis and retrieval of complex asset information. It is scalable to your specific needs, whether it is operator inspection rounds, on-line and periodic condition monitoring data collection or in-depth vibration analysis and expert advice.
- SKF @ptitude Inspector
SKF @ptitude Inspector is the SKF @ptitude Analyst software specifically targeted for ODR use. Combined with the SKF Microlog Inspector / SKF MARLIN system, it enables operations personnel to make their rounds, collecting machine condition, inspection and process data easily and efficiently in the palm-sized unit.
- SKF @ptitude Observer
SKF @ptitude Observer's easy-to-use operator interface and intelligent diagnostics functions provide users of all levels the tools needed to set up and run effective on-line monitoring programmes.
- SKF Customized Interfacing
he SKF Customized Interfacing is a fully-customized solution tailored to your unique process and business requirements. It connects your SKF @ptitude software to ERP, CMMS, EAM and other IT systems. By integrating data across systems and automating previously manual interactions, this custom interface helps simplify and optimize process monitoring and performance.

NAME: ThingWorx	
PRODUCER: PTC (USA)	
CATEGORY: Data Analytics platform	
REFERENCES: https://www.ptc.com/en/resources/iot/product-	
KEYWORDS: platform, data analysis, predictive maintenance, Condition monitoring	**BUSINESS SECTOR AND EVALUATION:**
KEY PERFORMANCE INDICATOR (if possible): n/a	**LICENSE:** Payment

DESCRIPTION: The ThingWorx platform is a complete, end-to-end technology platform that enables industrial businesses to unlock the value of the Internet of Things (IoT). It delivers tools and technologies needed to rapidly develop and deploy powerful applications and augmented reality (AR) experiences. The ThingWorx platform includes compatible modules that deliver the functionality, flexibility, and agility enterprises need to implement IoT apps and AR experiences. This includes industrial connectivity, analytics, application enablement, orchestration and AR authoring.
ThingWorx delivers:
• Purpose-built Platform: The platform contains specific functionality designed with the scalability and security to grow as the business expands.
• Rapid Development, Deployment, and Extensibility: Platform modules come together via the ThingModel– the true digital representation of a physical object – enabling apps and experiences to be delivered quickly and easily
• Ultimate Flexibility: Platform can be deployed in the cloud, on premise, or a hybrid of the two. Apps and experiences are made available to users in multiple formats – desktop, web, mobile, and AR. Integration with external data sources simplifies processes and ensures more meaningful results
• Vibrant Ecosystem: ThingWorx partner ecosystem offers one of the world's largest networks of IoT-focused companies, and ThingWorx partners offer a wide range of products and services that simplify, accelerate, or enhance processes and strategies for industrial IoT

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NAME: Smart Condition Monitoring	
PRODUCER: Mitsubishi Electric (USA)	
CATEGORY: Data Analytics platform	
REFERENCES: https://eu3a.mitsubishielectric.com/fa/en/solutions/	
KEYWORDS: platform, data analysis, predictive maintenance, Condition monitoring	**BUSINESS SECTOR AND EVALUATION:**
KEY PERFORMANCE INDICATOR (if possible): n/a	**LICENSE:** Payment

DESCRIPTION: The Smart Condition Monitoring (SCM) solution from Mitsubishi Electric provides an integrated approach to monitoring the condition of individual assets and enables a holistic approach to be taken to monitoring the asset health of the whole plant. Individual sensors provide both an in-built 'traffic light' warning indication at the machine, but at the same time plain text information from multiple sensors is transferred over Ethernet to the smart sensor controller for in-depth monitoring and more detailed analysis.
The SCM analysis provides detailed diagnostics, offers suggestions for where additional measurements should be taken, and provides maintenance staff more precise error identification with identifying the root case and even recommendations as to what rectification actions should be taken, with clear text messages presented to personnel. This information can be networked to higher-level systems for ongoing trend analysis across all of the assets around the plant.
Operational benefits:
- Predictable maintenance month before breakdown
- Reliable online monitoring of the machine
- Intelligent process monitoring
- Easy installation
- Intuitive operation
- Long term storage of historical data
- Flexible, expandable system
- Full service around machine diagnosis

The Smart Condition Monitoring system supports a number of functions that aid in predictive maintenance:
- Bearing defect detection
- Imbalance detection
- Misalignment
- Lack of lubricant detection
- Temperature measurement
- Cavitation detection
- Phase failure recognition
- Resonance frequency detection

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2.1.4. Patents Analysis

The aim of the patent analysis is to identify:

- ✓ Information about which area is more active in patenting in which geographical region;
- ✓ Information about which technology is "growing" and the growing rate;
- ✓ Information about which are the organizations investing in the different technologies (when they started, where are based, which results they achieved);
- ✓ Information about who (enterprises, research org, university labs, etc.) owns the most relevant IPR(Intellectual Property Rights) in a specific sector.

The tool used is Derwent Innovation suite[4], a comprehensive solution that combines intellectual property, scientific literature, news and business information, integrated with powerful analytics in a robust ICT platform. Derwent Innovation includes the databases of more than forty patent offices worldwide and 90% of the world's top filers. As a starting point, a smart combination of keywords and logical operators (Boolean Operators) will be defined, in order to mine the databases, extract all the relevant information and avoiding, at the same time, redundancies or background noise.

In the case of UPTIME Task 1.1 keywords used to perform this analysis on Derwent Innovation are:

platform AND (prediction OR predictive) AND maintenance

Where AND/OR are Boolean Operators used to find records containing *all terms* separated by the operator and to find records containing *any* of the terms separated by the operator respectively. The scope of this search was to obtain the biggest number of concept or existing platforms to operate real-time maintenance on industrial systems.

Considering a temporal range starting from 2001 to nowadays, the number of patents resulting from the database is 175 INPADOC[5] patent family. In the following figures are reported some data trends concerning the patents dataset analyzed in geographical area and patents application volume for each year.



Figure 2.2: Top Countries and Territories with a high number of patents deposition

China is the country with the most relevant number of deposited patents (141), this is due to a particular attention on this topic paid by several Chinese universities, technology companies and

[4] https://clarivate.com/products/derwent-innovation/

[5] INPADOC, which stands for INternational PAtent DOCumentation, is an international patent collection. The database is produced and maintained by the European Patent Office (EPO). It contains patent families and legal status information, and is updated weekly. An INPADOC patent family is a collection of patent applications covering the same or similar technical content.

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energy sector companies. The United States is following China with 59 patents only focused on a platform dedicated to predictive maintenance, in this group of patents in possible to find some important companies assignee such as Siemens and Airbus which are European companies with deposition of intellectual properties in The United States. Europe occupies the third place with the deposition of 30 patents about predictive maintenance platform.

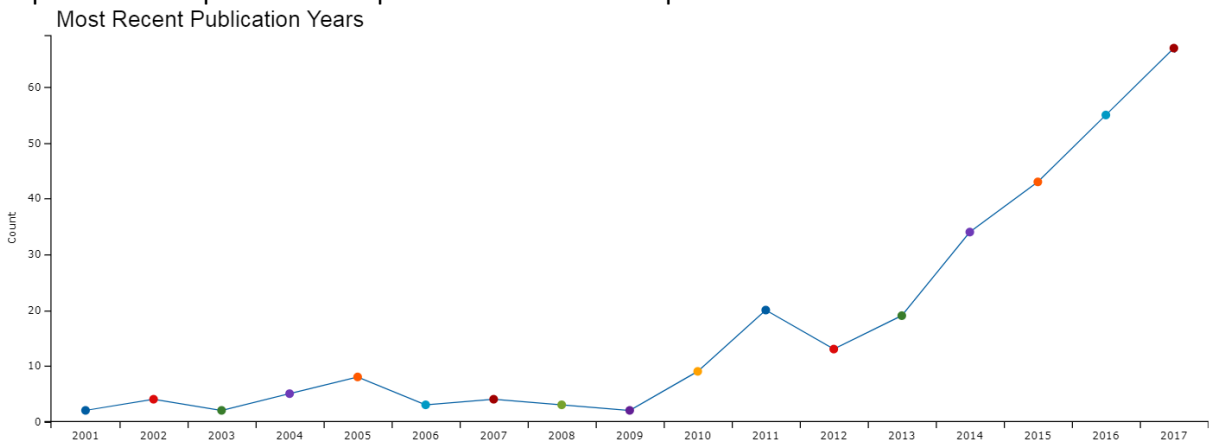


Figure 2.3: Trend of patents deposition starting from 2001 until 2018

Before 2009, the number of patents deposited about predictive maintenance was not significant and not always focused on online platforms for predictive maintenance. Starting from 2010, except for 2012, the number of patents deposited on this topic is strong growth; this factor is due to a significant interesting on this topic thanks to important technological developments and an economical growing from developing countries such as Southeast Asia.In this patent dataset it's possible to individuate a set of interesting keywords describing the main aspects and insights of the selected patents. The principal patents focus is on a deployment of real-time platform with functions act to perform online monitor on industrial equipment's, secondly, it's often present a focus on the power consumption monitoring, resource managing and processing times act to minimize industrial costs. In general, there is growth towards mass data processing and the IoT (Internet of Things) sector to obtain an overall vision on the industrial process starting from the Predictive Maintenance analysis.

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MAINTENANCE MANAGEMENT OF A MACHINE - US7496475B2

TITLE DWPI: Machine's e.g. truck, maintenance management providing method for use in e.g. power generation industry, involves modifying method of providing maintenance management based on performance indicators

PUBLICATION NUMBER (KIND CODE): US7496475B2

INVENTOR(S): Brian Dara Byrne, Poway, CA (US); Kevin Brady, San Marcos, CA (US); Arthur Stack, San Diego, CA (US)

ASSIGNEE: Solar Turbines Incorporated

PUBLICATION YEAR: 2009-02-24 (B2)

CURRENT IPC: G06F 11/30
G06F 15/00

DRAWING:

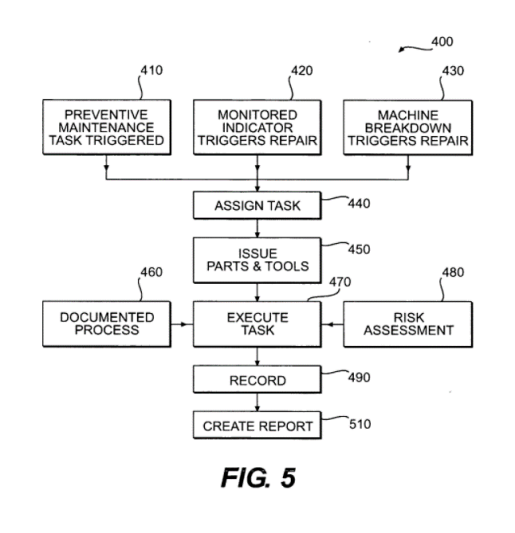


FIG. 5

ABSTRACT: Methods of providing maintenance management of a machine are disclosed. In one embodiment, the method involves identifying a machine component failure that, if not repaired, will result in a functional failure of the machine. A criticality factor is assigned to the machine component failure based on at least a probability of occurrence of the functional failure and a consequence of the functional failure to a machine user. A maintenance task is generated to repair the machine component failure, and a triggering condition that activates the maintenance task is defined. The method further involves conducting a machine repair in response to a detection of the triggering condition, and maintaining a record that includes information relating to the conducted machine repair. The method of providing maintenance management is also modified based on at least the record.

NOVELTY: The method involves assigning a criticality factor to a machine component failure based on a probability of occurrence of the functional failure and a consequence of the functional failure to a machine user, and generating a maintenance task to repair the machine component failure. A triggering condition is defined for activating a maintenance task. A machine repair is conducted in response to a detection of the triggering condition. A method of providing maintenance management is modified based on performance indicators.

USE: Method for providing maintenance management of a fixed machine e.g. turbine, and a mobile machine e.g. truck, crane, earth moving vehicle, mining vehicle, backhoe, material handling equipment, marine vessels and aircraft, located at a geographically separated worksite in an industry such as mining industry, construction industry, farming industry and power generation industry.

ADVANTAGE: The method effectively optimizes the reliability and performance of the machine with reduced cost and time.

DRAWING DESCRIPTION: The drawing shows a flowchart of a maintenance strategy development process for providing maintenance management of a machine.

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AN ONLINE MONITORING AND FAULT LOCATING FAILURE ANALYSIS AND CONTROL METHOD - CN107357228A

TITLE DWPI: Online monitoring fault analysis and control method, involves obtaining data on data collecting device, and displaying data in multiple desired failure mode prediction reports during data	**DRAWING: n/a**
PUBLICATION NUMBER (KIND CODE): CN107357228A	
INVENTOR(S): LIU M; YAO L; ZHANG L	
ASSIGNEE: Zte Yaowei Technology Jiangsu Co. Ltd.	
PUBLICATION YEAR: 2017-11-17 (A)	
CURRENT IPC: G05B 19/048	

ABSTRACT: The invention claims an online monitoring and fault locating failure analysis and control, wherein the method comprises the following steps: step 1, disposing sensor on the device needing to be monitored, step 2. the sensor collects the information passed on to local and cloud infrastructure platform server through local area network by the data collector, step 3, through continuously capturing data, establishing data model data, continuously by using the model iteratively comparing historical data, step 4, by repeating data check after iteration given damage index data bringthe and factory quality comparison. In the invention, the expandability of the cloud management is safe, convenient upgrading, receiving each area local collecting end server reports the data, classifying the data, storing, analyzing, displaying and operation, no need to manual management, realizing the intelligent;

NOVELTY: The method involves obtaining data on a data collecting device. Collected data is displayed in a security gate through a sensor. A safety gate signal is transmitted to the data collecting device. Information is stored on a local and cloud infrastructure platform server through a local area network. Database is established on local database. The data is collected by using a data modeling and iterative analysis process in real-time. The data is displayed in multiple desired failure mode prediction reports during a data analysis process of spare parts and maintenance plan.

USE: Online monitoring fault analysis and control method.

ADVANTAGE: The method enables improving cloud management expandability so as to ensure better storing, analyzing and displaying operation of the data without need of manual management operation in an effective manner.

DRAWING DESCRIPTION: n/a

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AN ONLINE MONITORING AND FAULT LOCATING FAILURE ANALYSIS AND CONTROL METHOD - CN107357228A

TITLE DWPI: Online monitoring fault analysis and control method, involves obtaining data on data collecting device, and displaying data in multiple desired failure mode prediction reports during data	**DRAWING: n/a**
PUBLICATION NUMBER (KIND CODE): CN107357228A	
INVENTOR(S): LIU M; YAO L; ZHANG L	
ASSIGNEE: Zte Yaowei Technology Jiangsu Co. Ltd.	
PUBLICATION YEAR: 2017-11-17 (A)	
CURRENT IPC: G05B 19/048	

ABSTRACT: The invention claims an online monitoring and fault locating failure analysis and control, wherein the method comprises the following steps: step 1, disposing sensor on the device needing to be monitored, step 2. the sensor collects the information passed on to local and cloud infrastructure platform server through local area network by the data collector, step 3, through continuously capturing data, establishing data model data, continuously by using the model iteratively comparing historical data, step 4, by repeating data check after iteration given damage index data bringthe and factory quality comparison. In the invention, the expandability of the cloud management is safe, convenient upgrading, receiving each area local collecting end server reports the data, classifying the data, storing, analyzing, displaying and operation, no need to manual management, realizing the intelligent;

NOVELTY: The method involves obtaining data on a data collecting device. Collected data is displayed in a security gate through a sensor. A safety gate signal is transmitted to the data collecting device. Information is stored on a local and cloud infrastructure platform server through a local area network. Database is established on local database. The data is collected by using a data modeling and iterative analysis process in real-time. The data is displayed in multiple desired failure mode prediction reports during a data analysis process of spare parts and maintenance plan.

USE: Online monitoring fault analysis and control method.

ADVANTAGE: The method enables improving cloud management expandability so as to ensure better storing, analyzing and displaying operation of the data without need of manual management operation in an effective manner.

DRAWING DESCRIPTION: n/a

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A METHOD AND DEVICE OF ESTIMATED REPAIR TIME - CN107203815A

TITLE DWPI: Maintenance time predicting method, involves determining maintenance correction coefficient, and estimating repair time of product to be maintained according to coefficient of each maintenance motilin standard maintenance action time	**DRAWING: n/a**
PUBLICATION NUMBER (KIND CODE): CN107203815A	
INVENTOR(S): FENG W; GENG J; HUANG M; LV C; WANG W; ZHANG W	
ASSIGNEE: Beihang University, Beijing	
PUBLICATION YEAR: 2017-09-26 (A)	
CURRENT IPC: G06Q 10/00 G06Q 10/06	

ABSTRACT: The invention claims a method and device estimated repair time, relating to the maintenance time prediction technology field, the method comprises: through to maintenance task of the maintain products to maintain decomposition, obtaining multiple maintenance action element; using the virtual maintenance simulation platform by a predetermined action time obtains each of maintenance time of standard maintenance action; the maintenance factor of the maintain products, determining each maintenance standard maintenance action time of maintenance correction coefficient, motilin standard maintenance action time according to each of determined maintenance maintenance correction coefficient; estimated repair time of the product to be maintained.

NOVELTY: The method involves obtaining multiple maintenance action elements through maintenance products under-maintenance task to maintain decomposition. Standard maintenance action time of each maintenance motilin is obtained using virtual maintenance simulation platform. A maintenance correction coefficient is determined for the standard maintenance action time using a maintenance factor of the maintenance products. Repair time of a product to be maintained is estimated according to the maintenance correction coefficient of each determined maintenance motilin standard maintenance action time.

USE: Maintenance time predicting method.

DRAWING DESCRIPTION: n/a

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A FAULT PREDICTION METHOD AND FAULT PREDICTION PLATFORM OF VEHICLE EQUIPMENT SYSTEM - CN107462425A

TITLE DWPI: Method for predicting fault of vehicle device system, involves inputting real-time state information to simulation environment, and generating prediction analysis result according to historical state data and real-time state information

DRAWING: n/a

PUBLICATION NUMBER (KIND CODE): CN107462425A

INVENTOR(S): CAO X; HAO X; ZHANG X

ASSIGNEE: Beijing Institute of Space Launch Technology

PUBLICATION YEAR: 2017-12-12 (A)

CURRENT IPC: G01M 17/007

ABSTRACT: The invention claims a method for predicting fault and fault prediction platform of vehicle equipment system, the method comprising the step of simulating building environment, the step of obtaining history information obtaining step and fault tendency of state information of a prediction step, the platform comprises a system setting module, an information communication module, a state monitoring module and a simulation test module. The invention not only solves the problems of multiple vehicle models, many or a few maintenance personnel cannot be ensured under the condition that the vehicle reliability, but also the different uniform application to a platform performing failure prediction based on simulation testing and verification, to avoid independent development simulation platform needs to be established for each application, therefore, the invention can greatly save the development cost, shorten the development period and improve the development efficiency.

NOVELTY: The method involves obtaining historical state data stored in a vehicle device system. The historical state data is input to a simulation environment. Real-time state information of a sensor on sub-systems in the vehicle device system is collected. The real-time state information is input to the simulation environment. A prediction analysis result is generated according to the historical state data and the real-time state information, where the prediction analysis result comprises vehicle fault prediction information and trend evaluation information.

USE: Method for predicting fault of a vehicle device system.

ADVANTAGE: The method enables ensuring vehicle reliability, performing failure prediction based on simulation testing and verification to avoid independent development simulation platform needs to be established for applications so as to save development cost, reduce development period and improve development efficiency.

DRAWING DESCRIPTION: n/a

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AN EQUIPMENT FAILURE PREDICTION SYSTEM AND METHOD - CN106991502A

TITLE DWPI: Device failure predicting system, has prediction module for predicting failure in device, analyzing unit for analyzing sensor data, and learning and processing prediction unit for learning and processing predicting failure type of device	**DRAWING: n/a**
PUBLICATION NUMBER (KIND CODE): CN106991502A	
INVENTOR(S): WIMULIN I; YOU J	
ASSIGNEE: Shenzhen Dasudian Technologies Ltd.	
PUBLICATION YEAR: 2017-07-28 (A)	
CURRENT IPC: G06Q 10/04 G06F 17/14	

ABSTRACT: The invention claims an equipment failure prediction system and method, the system comprising: a prediction module, the device failure prediction, the presenting module, out of the predicted failure to present the sensing data in the prediction module comprises: an acquisition unit, using the sensor real-time collect the device, analyzing unit for analyzing the sensor data, learning and processing prediction unit, based on said analysis, learning and processing predicting the fault type of the device. continuous processing and analysis through the data collection device and the real-time sampling data, make the device failure mode in the operation process is online learning, and realizes device fault on-line real-time tracking and prediction, so that the user can timely perform preventive maintenance for the device and prevent unscheduled stopping and accident.

NOVELTY: The system has a prediction module for predicting failure in a device. A presenting module is utilized for presenting sensing data. The prediction module is provided with an acquisition unit. The acquisition unit is provided with a sensor to collect data from the device in real-time. An analyzing unit is utilized for analyzing the sensor data. A learning and processing prediction unit is utilized for learning and processing predicting failure type of the device based on the analyzed data. A system main body is provided with a sensor data hub, an edge gateway and a cloud platform.

USE: Device failure predicting system

ADVANTAGE: The system realizes continuous processing and analysis the real-time sampling data through a data collection device so as to achieve online learning of operation process in a device failure mode thus tracking and predicting the device failure in on-line and real-time, hence preventing unscheduled device stopping and accident.

DRAWING DESCRIPTION: n/a

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SYSTEM AND METHOD TO FACILITATE WELDING SOFTWARE AS A SERVICE - WO2017019860A1

TITLE DWPI: Welding system e.g. robotic arc welding system has remotely situated analytics computing platform that employs learning algorithm to analyze welding data set and large dataset to predict characteristic of weld, weldment or weld process

PUBLICATION NUMBER (KIND CODE): WO2017019860A1

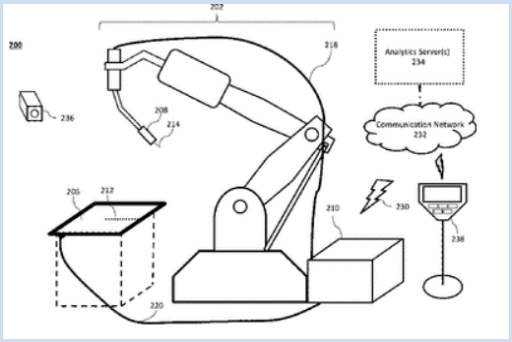
INVENTOR(S): HSU Christopher, US

ASSIGNEE: ILLINOIS TOOL WORKS INC., US

PUBLICATION YEAR: 2017-02-02 (A1)

CURRENT IPC: B23K 26/03 B23K 31/12
B23K 9/095 G05B 15/00
G06N 5/04 G06N 7/00
G06N 99/00 G06Q 10/06

DRAWING:



ABSTRACT: A weld production knowledge system for processing welding data collected from one of a plurality of welding systems, the weld production knowledge system comprising a communication interface communicatively coupled with a plurality of welding systems situated at one or more physical locations. The communication interface may be configured to receive, from one of said plurality of welding systems, welding data associated with a weld. The weld production knowledge system may comprise processing circuitry, wherein the processing circuitry is operatively coupled with the communication interface and a weld data store. The weld data store employs a dataset comprising (1) welding process data associated with said one or more physical locations, and/or (2) weld quality data associated with said one or more physical locations. The processing circuitry may employ a weld production knowledge machine learning algorithm to analyze the welding data vis-à-vis the weld data store to identify a defect in said weld.

NOVELTY: The system has a communication network (232) that communicates the welding data to remotely situated analytics computing platform (234). The remotely situated analytics computing platform associates the first welding data with second welding data to define a welding data set, and generates or updates a large scale dataset from heterogeneous data sources. The remotely situated analytics computing platform employs a production knowledge machine learning algorithm to analyze the welding data set and large scale dataset to predict a characteristic of weld, weldment or weld process.

USE: Welding system e.g. robotic arc welding system.

ADVANTAGE: The welding fabricators are used to optimize shifts for power consumption, service intervals and just-in-time service parts delivery, material flow and supply management in real time. The travel cost and software licensing maintenance cost are reduced. The acceptable accuracy of the weld production knowledge machine learning algorithm is ensured, so that the welding fabricator is provided with more efficient preventative/predictive maintenance (PPM) and condition-based maintenance (CBM) to reduce downtime and maintenance cost.

DRAWING DESCRIPTION: The drawing shows a schematic view of the robotic arc welding system.
202 - Control circuit.
208 - Welding tool.
212 - Weld joint.
232 - Communication network.
234 - Analytics computing platform.

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DIGITAL TWINS FOR ENERGY EFFICIENT ASSET MAINTENANCE - US20160247129A1

TITLE DWPI: System for using digital twins for scalable, model-based machine predictive maintenance, has simulation platform to process simulation models corresponding to multiple digital twins using multiple multiprocessor computer systems

PUBLICATION NUMBER (KIND CODE): US20160247129A1

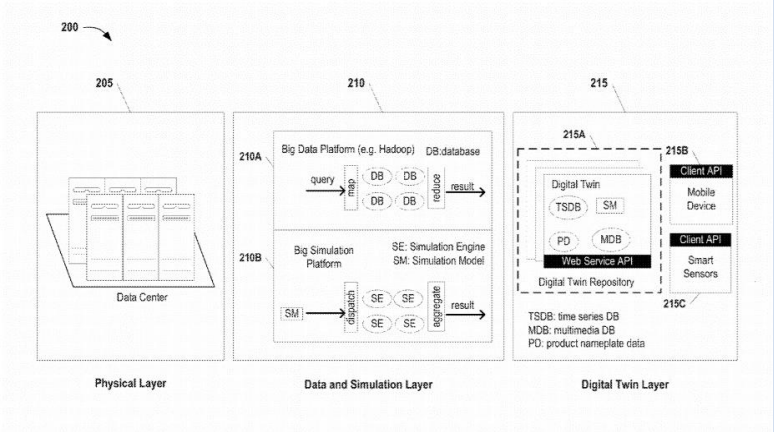
INVENTOR(S): MARTINEZ C A; SONG Z

ASSIGNEE: Siemens Corporation, Iselin, NJ, US

PUBLICATION YEAR: 2016-08-25 (A1)

CURRENT IPC: G06Q 10/00
G06Q 10/06

DRAWING:



ABSTRACT: A system for using digital twins for scalable, model-based machine predictive maintenance comprises a plurality of digital twins and a simulation platform. The plurality of digital twins correspond to plurality of remotely located physical machines. Each respective digital twin comprises: product nameplate data corresponding to a unique physical machine, one or more simulation models, and a database comprising run time log data collected from sensors associated with the unique physical machine. The simulation platform is configured to process simulation models corresponding to the plurality of digital twins using a plurality of multiprocessor computer systems.

NOVELTY: The system has multiple digital twins corresponding to multiple remotely located physical machines. Each respective digital twin comprises product nameplate data corresponding to a unique physical machine. A database has a run time log data collected from sensors. A simulation platform (210B) configured to process simulation models corresponding to multiple digital twins using multiple multiprocessor computer systems. A data platform (210A) configured to process multiple data query tasks using multiple multiprocessor computer systems.

USE: System for using digital twins for scalable, model-based machine predictive maintenance.

ADVANTAGE: The computer system can then identify one or more required maintenance tasks for the physical machine and send a notification of the one or more required maintenance tasks to an operator device. The end users are allowed to perform machine maintenance more efficiently by having access to detailed information regarding past, current, and predicted machine operations. Machines can be checked automatically or manually on a much more frequent basis which, in turn, results in quicker fault detection. The huge number of sequential simulation tasks can be distributed to be run simultaneously on the cloud that would provide unlimited computing resources. The amounts of minimal cloud computing resources needed for model simulation that satisfies user's needs should be calculated and allocated before launching model simulation.

DRAWING DESCRIPTION: The drawing shows a block diagram of a system for implementing a three-layer DT architecture.
205 - Physical layer.
210A - Data platform.
210B - Simulation platform.
215A - Repository.
215B - Mobile device application program interface.

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CLOUD-BASED EMULATION AND MODELING FOR AUTOMATION SYSTEMS - EP3037901A2

TITLE DWPI: Multi-tier industrial cyber analytics system for performing predictive analysis of industrial system, has analytics component which generates predictive data indicating predicted performance issue associated with industrial system

PUBLICATION NUMBER (KIND CODE): EP3037901A2

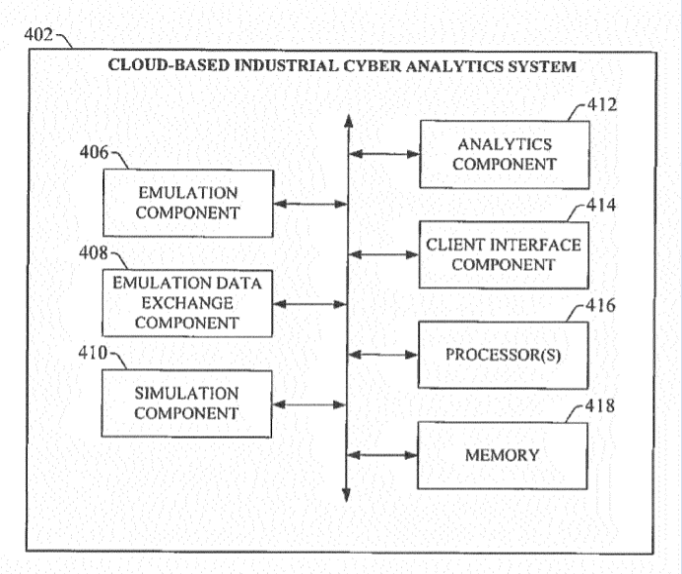
INVENTOR(S): ASENJO J L; KRIZ J; MANSOURI H; MATURANA F P

ASSIGNEE: Rockwell Automation Technologies Inc.

PUBLICATION YEAR: 2016-06-29 (A2)

CURRENT IPC: G05B 17/02
G06F 17/50

DRAWING:



ABSTRACT: A cloud-based multi-tier cyber analytics system is provided for integration of cloud-side and on-premise analytics for industrial systems. The analytics system includes an emulation runtime engine that executes a virtualized controller on a cloud platform. The runtime engine serves as a core analytics component by providing a control-level analytics engine with application programming interfaces (APIs) that enable seamless interaction of distributed simulations, cloud level services, and hardware industrial controllers. A cloud-based framework integrates soft control, hard control, and simulation with cloud-level services, and includes components that facilitate near real-time data streaming from the plant floor to the cloud platform to yield an industrial Internet of Things (IoT).

NOVELTY: The system (402) has an emulation component (406) which executes a virtualized industrial controller on a cloud platform. A simulation component (410) executes a simulation of an industrial system. An emulation data exchange component (408) executes an emulation data exchange interface (EDEI) that communicatively connects virtualized controller and simulation. An analytics component (412) generates predictive data indicating a predicted performance issue associated with industrial system based on analysis of a simulation session performed by the simulation and the virtualized controller.

USE: System for performing predictive analysis of industrial system.

ADVANTAGE: The cloud agents automatically detects and communicates with the cloud platform upon installation at any facility, simplifies integration with existing cloud-based data storage, analysis, or reporting applications used by the enterprise. The cloud platform allows software vendors to provide software as a service, removes the burden of software maintenance, upgrades, and backup from the customers. The pre-processing or data refinement facilitate efficient transfer of the data to the cloud, prepare the data for enhanced analysis in the cloud, and reduce the amount of cloud storage required to store the data. The analytics system simulation component automatically identifies possible alternative operating scenarios for optimizing or improving key performance indicators and models the operating scenarios in simulation.

DRAWING DESCRIPTION: The drawing shows a block diagram of the cloud-based industrial emulation and analytics system.
402 - Cyber analytics system.
406 - Emulation component.
408 - Emulation data exchange component.
410 - Simulation component.
412 - Analytics component.

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COMPUTER-IMPLEMENTED METHOD AND SYSTEM FOR MACHINE TOOL DAMAGE ASSESSMENT, PREDICTION, AND PLANNING IN MANUFACTURING SHOP FLOOR - US20160091393A1

TITLE DWPI: Computer-implemented system for e.g. detecting machine tool wear has remaining useful life prediction module that predicts machine tool's remaining useful life by extrapolating trend under first-order Markov process

PUBLICATION NUMBER (KIND CODE): US20160091393A1

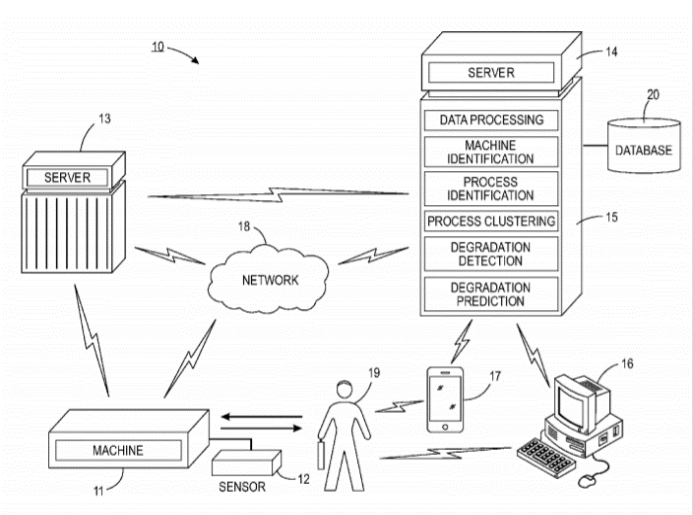
INVENTOR(S): KLEER J D; KURTOGLU T; LIAO L; MINHAS R S; RANGARAJAN A

ASSIGNEE: Palo Alto Research Center Incorporated

PUBLICATION YEAR: 2016-03-31 (A1)

CURRENT IPC: G01M 13/00
B23Q 17/09

DRAWING:



ABSTRACT: A self-aware machine platform is implemented through analyzing operational data of machining tools to achieve machine tool damage assessment, prediction and planning in manufacturing shop floor. Machining processes are first identified by matching similar processes through an ICP algorithm. Machining processes are further clustered by Hotelling's T-squared statistics. Degradation of the machining tool is detected through a trend of the operational data within a cluster of machining processes by a monotonicity test, and the remaining useful life of the machining tool is predicted through a particle filter by extrapolating the trend under a first-order Markov process. In addition, process anomalies across machines are detected through a combination of outlier detection methods including SOMs, multivariate regression, and robust Mahalanobis distance. Warnings and recommendations are flexibly provided to manufacturing shop floor based on policy choice.

NOVELTY: The system (10) has a process clustering module that clusters the machining processes into process clusters based on similarity of machining processes. A degradation detection model detects machine tool's wear by characterizing trend of change in parameter from clusters of machining processes performed by machine tool. A remaining useful life prediction module predicts machine tool's remaining useful life by extrapolating trend under first-order Markov process.

USE: Computer-implemented system for detecting machine tool wear of e.g. drill bit or milling cutters, predicting machine tool failure, and manufacturing shop floor planning.

ADVANTAGE: The state of wear and the remaining useful life of the machine tool are used to help managers or maintenance crew on manufacturing shop floor to make decisions. The accuracy and efficiency of early warning and objective advice in the manufacturing shop floor setting is greatly improved by combining both the anomaly detection and degradation assessment and prediction using the trend. The histogram of spindle loads weighted by the time spent at various spindle speeds is plotted and compared for two machines, which provides relative estimate of remaining useful life of the spindle bearings. The combination provides sufficient resolution and predictive power without requiring unrealistically high computing power. Allows moving the manufacturing shop from scheduled maintenance to condition-based maintenance that more closely reflects the damage accumulation.

DRAWING DESCRIPTION: The drawing shows a functional block diagram of a computer-implemented system for detecting degradation and predicting failure of a machine tool.
10 - System.
11 - Machine.
12 - Sensor.
13 - Web-based server.
14 - Centralized server.
15 - Program or module.

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A CLOUD PLATFORM MONITORING SERVICE SYSTEM AND METHOD BASED ON MASS DATA ANALYSIS - CN107070692A

TITLE DWPI: Large data analysis based cloud platform service monitoring system, has data acquisition layer provided with host and network resource collecting tool, and web application layer reads data from database,

DRAWING: n/a

PUBLICATION NUMBER (KIND CODE):
CN107070692A

INVENTOR(S): BAO Q; CHEN H; CHENG W; DENG G; GAO W; HUANG H; LAI B; LI S; LIN B; PAN R; SONG A; WEN B; XIE H; XIE X; YAO Y; YU J; YUE Q; ZHANG Y; ZHAO L; ZHENG Y

ASSIGNEE: Guangdong Branch of China United Network Communication Co. Ltd.

PUBLICATION YEAR: 2017-08-18 (A)

CURRENT IPC: H04L 12/24
H04L 12/26
H04L 29/08

ABSTRACT: The invention claims a cloud platform monitoring service system and method based on mass data analysis, wherein the system comprises a large data collection layer, a data processing layer and a web application layer; said data acquisition layer comprises a host, memory, collecting tool of the network resource and for collecting the web application layer data collecting program, the large data processing layer for all the data collected by the data acquisition layer is analyzed to generate maintenance index, and the index into the generated database; the web application layer reads data from the database, and to display and management at the front end. A cloud platform monitoring service system and method based on large data analysis provided by the invention, through large data intelligent analysis result, can bring health index of the food safety electronic tracing cloud service platform to the manager and intelligent suggestion for administrator provide decision assistance.

NOVELTY: The system has a data acquisition layer provided with a host, a memory and a network resource collecting tool. A data collecting program is installed on a web application layer. A large data processing layer collects data by the data acquisition layer to generate a maintenance index. The web application layer reads the data from database, where the data is displayed at a front end. The large data processing layer is provided with a performance prediction unit and a dynamic threshold value generating unit. The performance prediction unit collects operation trend history data.

USE: Large data analysis based cloud platform service monitoring system.

ADVANTAGE: The system recommends health index of a food safety electronic tracing cloud service platform to a manager through an intelligent large data analysis result to provide decision assistance for an administrator in a convenient manner.

DRAWING DESCRIPTION: n/a

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REAL TIME MACHINE LEARNING BASED PREDICTIVE AND PREVENTIVE MAINTENANCE OF VACUUM PUMP - US20160245279A1

TITLE DWPI: Method for predictive and preventive maintenance of vacuum pumps by machine learning architecture involves analyzing blower sensor data in association with motor sensor data to detect deficient oil level and deficient oil structure

PUBLICATION NUMBER (KIND CODE): US20160245279A1

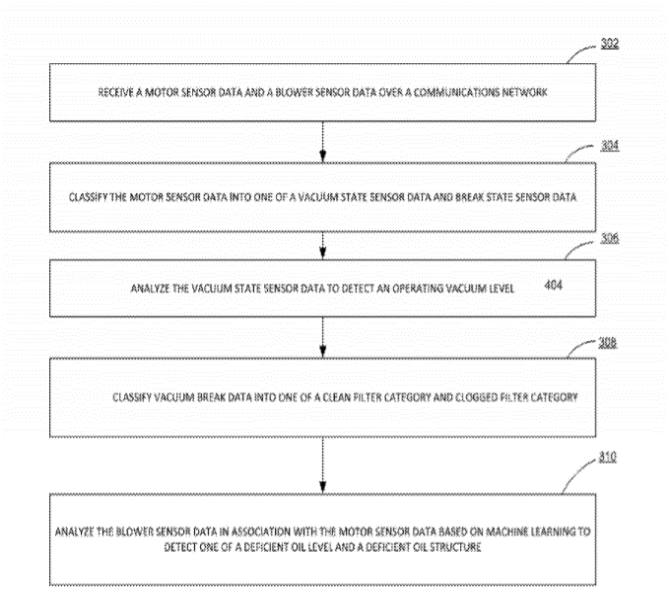
INVENTOR(S): GILLMEISTER S; PAL B; PUROHIT A

ASSIGNEE: GILLMEISTER S; PAL B; PUROHIT A

PUBLICATION YEAR: 2016-08-25 (A1)

CURRENT IPC: F04B 51/00
G01N 15/08
G01M 3/02

DRAWING:



ABSTRACT: A method and system of a machine learning architecture for predictive and preventive maintenance of vacuum pumps. The method includes receiving one of a motor sensor data and a blower sensor data over a communications network. The motor sensor data is classified into one of a vacuum state sensor data and break state sensor data. The vacuum state sensor data is analyzed to detect an operating vacuum level and an alarm is raised when the vacuum state sensor data exceeds a pre-defined safety range. Vacuum break data is classified into one of a clean filter category and clogged filter category and an alarm is raised if an entry under the clogged filter category is detected. The blower sensor data in association with the motor sensor data is analyzed based on machine learning to detect one of a deficient oil level and a deficient oil structure.

NOVELTY: The maintenance method involves classifying (304) received motor sensor data and/or blower sensor data into one of a vacuum state sensor data and break state sensor data, analyzing (306) the vibration data of the vacuum state sensor data to detect an operating vacuum level, and classifying (308) vacuum break data into one of a clean filter category and clogged filter category. The blower sensor data is analyzed (310) in association with the motor sensor data based on machine learning to detect deficient oil level and deficient oil structure.

USE: Method for predictive and preventive maintenance of vacuum pumps by a machine learning architecture (claimed). Can be used with an Internet of Things (IoT) based system for overseeing process control and predictive maintenance of a machine or a network of machines by employing machine wearable sensors.

ADVANTAGE: By comparing the blower data for good and bad oil using supervised machine learning, operation with bad oil may be detected. By comparing with the baseline operation, a mobile application may indicate degradation of filters and drying process, may offer recommended operation for optimal temperature to save energy and may act as a platform for dryer maintenance. The machine learning module associated with the tracking module may identify a pattern from the temperature, the sound and the vibration data and may raise an alarm based on an analysis of the pattern.

DRAWING DESCRIPTION: The drawing shows a process flow diagram detailing the operations of a method of a machine learning architecture.
302 - Receiving motor sensor data and blower sensor data.
304 - Classifying the motor sensor data.
306 - Analyzing the vacuum state sensor data.
308 - Classifying vacuum break data.
310 - Analyzing the blower sensor data.

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PBC ENTERPRISE EQUIPMENT MONITORING SYSTEM - CN104460596A

TITLE DWPI: PCB enterprise device monitoring system, has rotating speed sensor, temperature sensor, vibration sensor, reading device, rotating speed sensor, temperature sensor and vibration sensor connected with monitoring module	**DRAWING: n/a**
PUBLICATION NUMBER (KIND CODE): CN104460596A	
INVENTOR(S): YE Jiao-ran, CN	
ASSIGNEE: YE Jiao-ran, CN	
PUBLICATION YEAR: 2015-03-25 (A)	
CURRENT IPC: G05B 19/418	

ABSTRACT: The invention claims a PCB enterprise device monitoring system, wherein it comprises installed on processing device of speed sensor, a temperature sensor, a vibration sensor, a reading device, a rotating speed sensor, a temperature sensor, a vibration sensor, a reading device connected to the server through a network switch, a server connected to the handheld terminal, and a display, the main function comprises records operating state and fault monitoring and prediction. the manager can know the processing device/production in real time processing, standby, halt and maintenance state, adjusting the production plan in time, fully utilize enterprise productivity, and the device has a tiny abnormality timely maintenance so as to avoid device damage occurs serious fault, reduce the production cost of the enterprise.

NOVELTY: The system has a rotating speed sensor, a temperature sensor, a vibration sensor, a reading device, a rotating speed sensor, a temperature sensor and a vibration sensor connected with a monitoring module. A network switcher is connected with a server, a handheld terminal and a display unit, where the reading device is a scanning device or a hand-hold scanning identification device. The server is connected with a remote accessing module based on Internet service, where the handheld terminal is a mobile phone. The server is connected with a short message sending platform.

ADVANTAGE: The system has better damage-proof function, high processing efficiency, maintaining efficiency, production efficiency, working speed and low enterprise production cost.

DRAWING DESCRIPTION: n/a

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EMBEDDED PROGNOSTICS ON PLC PLATFORMS FOR EQUIPMENT CONDITION MONITORING, DIAGNOSIS AND TIME-TO-FAILURE/SERVICE PREDICTION - WO2013155421A1

TITLE DWPI: Method for determining prognostic information for equipment controlled by programmable logic controller, involves identifying operating condition of equipment and extracting features from data samples based on operating conditions

PUBLICATION NUMBER (KIND CODE): WO2013155421A1

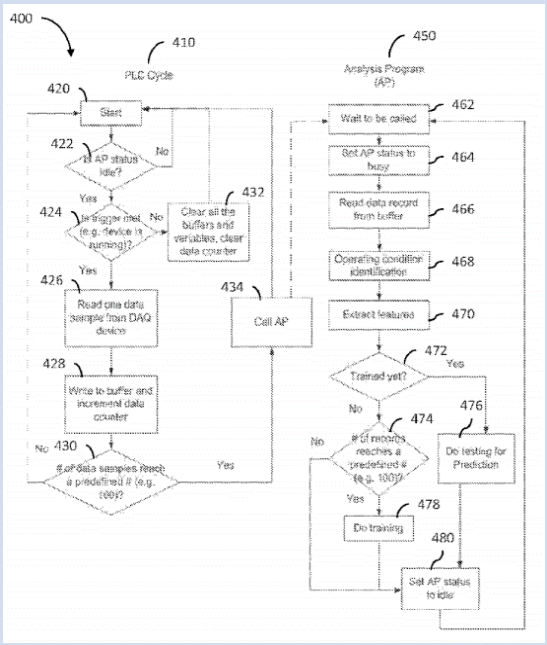
INVENTOR(S): EDMONDSON Z; ELIGUL E; LIAO L

ASSIGNEE: SIEMENS CORPORATION, US LIAO Linxia, US ELIGUL Ertan, TR EDMONDSON Zachery, US

PUBLICATION YEAR: 2013-10-17 (A1)

CURRENT IPC: G05B 19/05
G06F 11/00

DRAWING:



ABSTRACT: A prognostics analysis software module is embedded in a programmable logic controller (PLC) software platform. During cycling of the PLC real-time operating program, data is read from sensors and written to a buffer only when the prognostics analysis software module is idle. The prognostics analysis software module is then activated by a system function block of the PLC software platform. Before determining any prognostic information, prediction models within the prognostics analysis software module are automatically trained using features extracted from the sensor data.

NOVELTY: The method (400) involves determining whether a prognostic analysis program has an idle status. A predetermined number of data samples are read from a data acquisition device and the data samples are written to a buffer by the programmable logic controller if the prognostics analysis program has the idle status. The prognostics analysis program is activated to have an active status by a system function block. An operating condition of the equipment is identified (468) and multiple features are extracted (470) from the data samples based on the operating conditions.

USE: Method for determining prognostic information for equipment controlled by a programmable logic controller (Claimed), particularly for embedding prognostics analysis software in a programmable logic controller platform to perform equipment prognosis. Uses include but are not limited to machine tool components such as motor, gearbox, and bearing, gas or wind turbines and trains.

ADVANTAGE: The operating condition of the equipment is identified and multiple features are extracted from the data samples based on the operating conditions, thus identify and diagnose equipment faults during regular operations with minimum human intervention before a major failure occurs, the system alerts the user of the need for maintenance to be performed, using simple physical indicators such as lighting and if the health indicator exceeds a statistical or predefined threshold, diagnosis and prediction functions are triggered to determine the type of fault and potential remaining useful life or time to service. The system successfully detects and identifies anomaly situations of different imbalance faults on the motor loading.

DRAWING DESCRIPTION: The drawing shows a flow chart of a method for determining prognostic information for equipment controlled by a programmable logic controller.
400 - Method for determining prognostic information.
468 - Identifying operating condition of the equipment.
470 - Extracting multiple features.
472 - Determining prognostic information.
480 - Setting prognostics analysis program status to idle.

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PREDICTIVE MAINTENANCE FOR INDUSTRIAL PRODUCTS USING BIG DATA - EP2801938A1

TITLE DWPI: System for performing predictive analysis on industrial data e.g. firmware version, has predictive analysis component that predicts performance problem of industrial control system based on analysis of industrial data

PUBLICATION NUMBER (KIND CODE): EP2801938A1

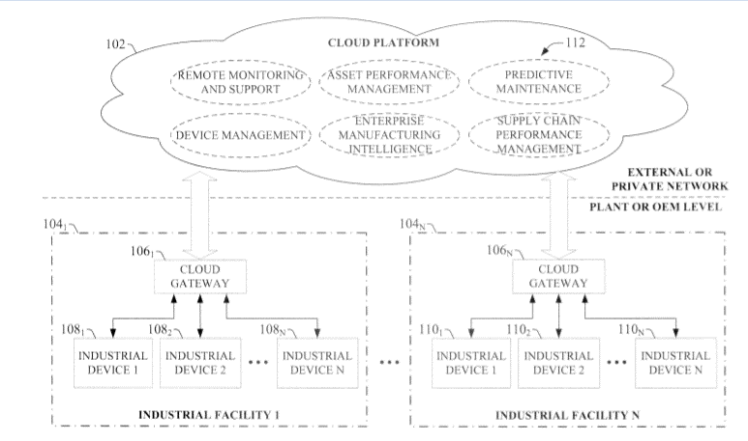
INVENTOR(S): ANSONJO J L; ASENJO J L; CANTY S T; CONTI S T; DICK J; DYCK J; EGERAAT B H; HALKURISH J A; HARKULICH J A; HEGRAT B H; HESMEL R; HESSMER R; HILL E A; KORPELA J L; NAVARANIYEK S T; NAWALANIEC S T; STROHMENGER J; WRICHT J R; WRIGHT J R

ASSIGNEE: ROCKWELL AUTOMATION TECH INC

PUBLICATION YEAR: 2013-10-17 (A1)

CURRENT IPC: G05B 13/02
G05B 19/418
G06Q 10/06

DRAWING:



ABSTRACT: A cloud-based predictive maintenance service collects industrial data from multiple industrial customers for storage and analysis on a cloud platform. The service analyzes data gathered from multiple customers across different industries to identify operational trends as a function of industry type, application type, equipment in use, device configurations, and other such variables. Based on results of the analysis, the predictive maintenance service predicts anticipated device failures or system inefficiencies for individual customers. Notification services alert the customers of impending failures or inefficiencies before the issues become critical. The cloud-based notification services also notify appropriate technical support entities to facilitate proactive maintenance and device management.

NOVELTY: The system has a device interface component that is configured to collect industrial data from a set of devices (108, 110) comprising an industrial control system and store the industrial data on a cloud platform (102). A predictive analysis component is configured to predict a performance problem of the industrial control system based on analysis of the industrial data. The device interface component is configured to store the industrial data on the cloud platform in association with a customer identifier.

USE: System for performing predictive analysis on industrial data such as industry type, industrial application type, industrial asset configuration, equipment type, industrial device configuration setting, firmware version, or software version for customer business such as automotive, food and drug, oil and gas, fibers and textiles, power generation, and marine. Can also be used in truck or other service vehicle.

ADVANTAGE: The documentation is accessed remotely and gather information necessary to identify the maintenance issue and provide personalized assistance. The industrial devices and/or cloud gateways having smart configuration capability are configured to automatically detect and communicate with the cloud platform upon installation at any facility. The integration with existing cloud-based data storage, analysis, or reporting applications used by the enterprise is simplified. The accurate and detailed documentation of each customer's devices, assets, and system configurations are maintained efficiently on cloud storage, thus the predictive maintenance system can automatically manage device firmware. The automated monitoring and maintenance of customer's industrial systems is provided even in the absence of plant personnel who possess sufficient knowledge of on-site assets.

DRAWING DESCRIPTION: The drawing shows a schematic block diagram of the industrial enterprise that leverages cloud-based services.
102 - Cloud platform.
104 - Industrial facilities.
106 - Cloud gateway.
108, 110 - Industrial devices.
112 - Computing services.

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A POWER EQUIPMENT STATE MAINTENANCE SYSTEM - CN103914791A

TITLE DWPI: Electric power device state inspection system, has maintenance strategy module detecting health status of power device, and system unit generating risk index and malfunction diagnostic reports according to repair decision information

DRAWING: n/a

PUBLICATION NUMBER (KIND CODE): CN103914791A

INVENTOR(S): CAI Y; LIN B; QIAN H; SUN M; WANG Q

ASSIGNEE: CHINA SOUTHERN POWER GRID CO LTD POWER S; GUANGZHOU ANDIAN MEASUREMENT & CONTROL

PUBLICATION YEAR: 2014-07-09 (A)

CURRENT IPC: G06Q 50/06

ABSTRACT: The invention claims a power equipment state maintenance system, comprising: the network system for producing I area data and the production III area data fusion of the maintenance platform; collecting the online monitoring data of electric power equipment by base platform. state monitoring module operating environment information, consulting state evaluation standard of the power device, the on-line monitoring data for evaluation to obtain on-line monitoring data representative of the power state of device health state evaluation module, consulting a risk evaluation standard of power equipment. calculating power device risk index of risk evaluation module, according to the health state and risk index of power equipment and fault diagnosis of the power device and producing fault diagnosis report of fault diagnosing module; according to the health state of the power device, the risk index and fault diagnosis report generating maintenance strategy module maintaining decision information of the power equipment. The invention improves the network system for automatic evaluation, evaluation and prediction, improves the power system automation and intelligent level.

NOVELTY: The system has a maintenance base platform provided with a power grid system body and formed with a production area. A state monitoring module is connected with the platform and stored with online monitor data and operation environment information. An electric power device obtains online monitor characteristic information from a risk evaluation module. A maintenance strategy module detects health status of the power device. Risk index and malfunction diagnostic reports are generated by a system unit according to repair decision information of the power device.

USE: Electric power device state inspection system.

ADVANTAGE: The system realizes power device state assessment and evaluation operations and improves power grid operating efficiency.

DRAWING DESCRIPTION: n/a

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ESTIMATING ACCURACY OF A REMAINING USEFUL LIFE PREDICTION MODEL FOR A CONSUMABLE USING STATISTICS BASED SEGMENTATION TECHNIQUE - US9046854B2

TITLE DWPI: Method for rapidly detecting anomalies in measurement and/or usage, involves applying statistical metrics to groups showing statistically different levels of prediction accuracy so as to alert user or service/maintenance provider

PUBLICATION NUMBER (KIND CODE): US9046854B2

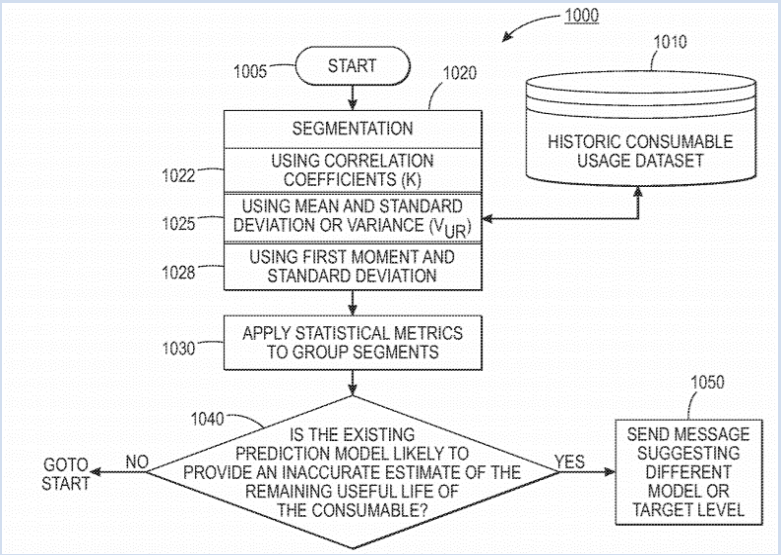
INVENTOR(S): XEROX CORP

ASSIGNEE: FOLEY D M; LI J; STUMBO W K; YANG M

PUBLICATION YEAR: 2015-06-02 (B2)

CURRENT IPC: G03G 15/08
G03G 15/00

DRAWING:



ABSTRACT: An apparatus and method of predicting the end of life of a consumable. A basic weighted least squares algorithm has been extended and augmented to compensate for observed common consumable/printer behavior. The system uses consumable usage data (such as toner level) acquired from the device to predict the current and future consumable level and to predict the remaining life. The apparatus and method monitors the consumable's usage and updates the prediction so that when the predicted remaining life matches a preset threshold, it automatically triggers an order placement event to ship product to customer.

NOVELTY: The method involves selectively segmenting (1020) consumables into groups showing statistically different levels of prediction accuracy by the features of the prediction models when a prediction is given by a prediction model applied to a historic consumable usage dataset. The statistical metrics is applied (1030) to groups showing accuracy so as to alert a user or a service/maintenance provider when remaining life prediction models do not yield accurate results for a given time window, so that a different prediction model or an alternative shipment triggering algorithm is employed.

USE: Method for rapidly detecting anomalies in measurement and/or usage for accurate estimation of supply level and remaining useful life of consumable such as toner in image reproduction devices such as digital copier or printer, image printing machine, digital production press, document processing system, image reproduction machine, bookmaking machine, facsimile machine and multi-function machine.

ADVANTAGE: The consumable is accurately estimated at any time during use. Since DFT performs centralized help desk system or device management system functions, the information regarding orders and target device information at the device management facility is maintained to insure data integrity. The accurate prediction is enabled when the toner level hits the target or provides notification when a prediction model needs to be replaced or changed.

DRAWING DESCRIPTION: The drawing shows a flowchart illustrating the method to alert user when a remaining life prediction models do not yield accurate results for a given time window.
1020 - Step for segmenting consumables into groups.
1022 - Step for using correlation coefficients.
1028 - Step for using first moment and standard deviation.
1030 - Step for applying statistical metrics to groups.
1050 - Step for sending message suggesting different model or target level.

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METHOD, SYSTEM AND APPARATUS FOR INTELLIGENT MANAGEMENT OF OIL AND GAS PLATFORM SURFACE EQUIPMENT - US8676721B2

TITLE DWPI: Computer implemented performance predicting method for surface equipment used in oil and gas field platforms located offshore/onshore, involves providing display system for displaying formatted sensor data to end users

PUBLICATION NUMBER (KIND CODE):
US8676721B2

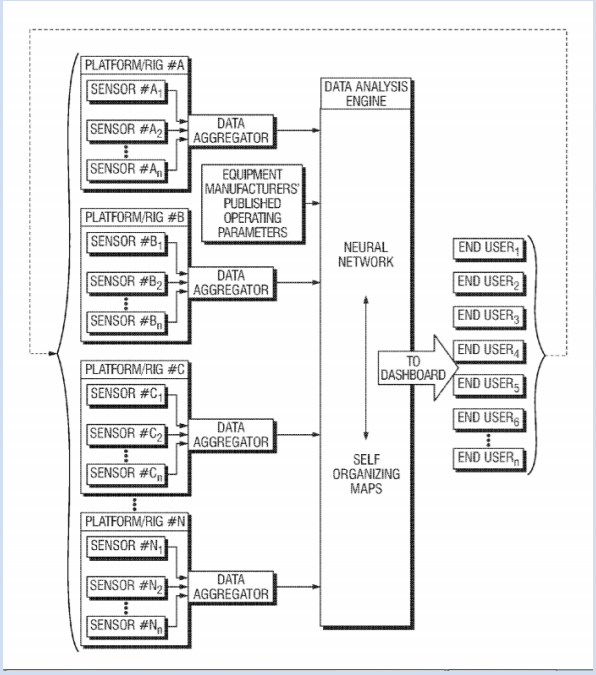
INVENTOR(S): KOZMAN J B; PIOVESAN C M

ASSIGNEE: APO OFFSHORE INC; PIOVESAN CAROL M; KOZMAN JESS B

PUBLICATION YEAR: 2014-03-18 (B2)

CURRENT IPC: G06F 15/18
G06F 17/00
G06F 17/20
G06F 19/00

DRAWING:



ABSTRACT: A method, system, apparatus (and related computer program) for intelligent management of oil and gas offshore and onshore platform surface equipment over a computer network is disclosed. The system utilizes a data aggregator for gathering real-time data streams from surface equipment located on such platform(s), such surface equipment containing one or more sensors for monitoring in real time the performance of equipment operational parameters of interest. The data analysis engine is in network communication with the data aggregator, and comprises a trained neural network capable of generating self organizing maps, and creating predictive operational parameters regarding such surface equipment. An interface is provided for inputting into the neural network various data including, for example, the published performance operational parameters for such equipment. A network user interface is also provided for transmitting such predictive operational input to one or more end user terminals equipped with end user dashboard display software.

NOVELTY: The method involves providing a neural network within a data analysis engine, and generating self organizing maps within the data analysis engine. A neural network engine is used to transform equipment data streams from a monitoring state to a predictive state. Status indicators in real-time relevant to operation of an equipment are generated, where the status indicators are transmitted to a set of end users over a network. A computer-based dashboard software-based display system is provided for displaying formatted sensor data to the end users.

USE: Computer implemented method for remotely predicting performance of a surface equipment used in oil and gas field platforms located offshore/onshore.

ADVANTAGE: The method enables supporting critical business drivers and workflows, while ensuring equipment downtime reduction, reliability improvement, secure maintenance and efficiency and energy-consumption optimization. The data analysis engine enables root-cause-failure analysis and early identification of pending equipment wear-out or failure, thus providing justification to operators for extended overhaul periods in a cost-effective manner.

DRAWING DESCRIPTION: The drawing shows a block diagram of an intelligent platform system.

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3. Conclusion and Outlook

At the end of this previous massive analysis, looking at the “State-of-Play Analysis on Predictive Maintenance Models, Techniques & Platforms” of the UPTIME Project, it was possible to collocate it within the curve of technology evolution as in the development phase. This result is supported by the trend of patent deposition that identifies a growth in the number of patent starting from 2010. In the collected patent dataset it’s possible to individuate a set of interesting keywords describing the main aspects and insights of the selected patents. The principal patents focus is on a deployment of real-time platform with functions act to perform online monitor on industrial equipment’s, secondly, it’s often present a focus on the power consumption monitoring, resource managing and processing times act to minimize industrial costs. In general, there is growth towards mass data processing and the IoT (Internet of Things) sector to obtain an overall vision on the industrial process starting from the Predictive Maintenance analysis.

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