UPTIME
UNIFIED PREDICTIVE MAINTENANCE

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Deliverable 1.1a,b
State-of-Play Analysis (Catalogue) of PM Models, Techniques & Platforms

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1.0	Inclusion of additional Commercial Platforms	Mews and Rina Consulting
1.1	D1.1a,b – updates 2nd iteration and final version	Rina Consulting
1.2	ISADEUS Review	ISADEUS
2.0	Final version addressing reviewer feedback	Rina Consulting

Reviewer

Name	Organisation
Yvon Chang (D1.1a)	Mews Partners
Yves KERARON (D1.1b)	ISADEUS

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List of Abbreviations

CMS	Content Management System
CBM	Condition Based Maintenance
EPO	European Patent Office
INPADOC	INternational PAtent DOCumentation
IoT	Internet of Things
KPI	Key Performance Indicator
PHP	PHP: Hypertext Preprocessor
PM	Predictive Maintenance
R&D	Research and Development
TRL	Technology Readiness Level
UPTIME	Unified PredicTIve MaintenancE

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Executive Summary

The UPTIME deliverable 1.1 will set the basis of the UPTIME project by analysing, on the basis of a structured methodology and selected KPIs, a number of 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 the state of play in predictive maintenance covering a broad spectrum of platforms that involve several kinds of PM models and techniques. Then D1.1 will be used as input by several tasks in WP1 and WP2.

The analysis was performed through desktop search, analysis of previous FP7 and H2020 projects (from 2012 onwards) and with a massive patent analysis. For patents section, the tool used is Derwent Innovation suite[1], 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 239 INPADOC[2] patent family. China is the country with the most relevant number of deposited patents (197), this is due to particular attention on this topic paid by several Chinese universities, technology companies and energy sector companies. In accordance with the System Evolution Theory formulated by G. Altshuller[3], evaluating and comparing the outputs of deliverable 1.1, it is possible to collocate the UPTIME platform in the *development phase* of the curve of technology evolution. UPTIME project already passed the early infancy stage and all efforts of partner involved in the project are on the maximisation and implementation of the performances. This evaluation is based on the study of UPTIME project and it is also based on a comparing process with the outputs of the Deliverable 1.1 (patents, literature, etc) that are strictly correlated to the results of the market analysis in D8.1.

The final output of the D1.1a,b is presented in the form of a web-based platform, a specific tool provided by RINA Consulting called Strategic Intelligence Platform (https://uptime.dappolonia-innovation.com/). With this tool is it possible to have a wide and smart vision on the Predictive Maintenance world based on commercial and R&D active players, relevant intellectual properties and scientific publications.

[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.

[3] https://triz-journal.com/technology-maturity-using-s-curve-descriptors/

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1. Introduction

1.1. Objectives of UPTIME Deliverable 1.1

Objective of this deliverable is to create a catalogue of Predictive Maintenance models, techniques and platform and defining a state of art relevant to the PM sector. This deliverable will set the basis of the UPTIME project by analysing, on the basis of a structured methodology, a number of 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. The results of this analysis will be inserted in a web-based database organized by 4 macro subjects (Market & Players, R&D, IP, Scientific Publication) and supported by a report.

In particular, this deliverable provides information regarding the state of play in predictive maintenance covering a broad spectrum of platforms that involve several kinds of PM models and techniques that could be useful for UPTIME's requirements and the platform's development. The Deliverable 1.1 will be used as input by several tasks in WP1 and WP2. In particular, Task 1.3[4] and Task 1.4[5] 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[6] 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 with respect to 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 outcome is the UPTIME catalogue of Models, Technologies and Platform categorized according to the field of applications, highlighting those that are relevant to the three project business cases.

General aspects of Predictive Maintenance

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.

[4] This task (T1.3) will create a taxonomy of the different data sources related to predictive maintenance at the shopfloor and in manufacturing operations. Each data source will be analysed in order to define the relevant processes and the data schemas / formats of the outputs, while identifying the expected volume, velocity and veracity aspects of the data transferred. Based on the information collected regarding the data acquisition phase, appropriate data curation, integration and (near real-time) processing patterns will be developed in order to provide the necessary background for data ingestion, streaming and (predictive) analytics in alignment with state-of-the-art big data techniques and technologies.
[5] The objective of this task (T1.4) is to establish a common understanding across the different disciplines represented in the project regarding the underlying theories, models and algorithms with respect to Diagnosis, Prognosis and Maintenance Decision Making. Based on the state of the art analysis performed in T1.1 and the generic UPTIME model, concepts and workflows developed in T1.2 of this proposal, we will perform a survey on algorithms existing in prototype and industrial predictive maintenance information systems as well as in literature in the areas of Diagnosis, Prognosis and Maintenance Decision Making.
[6] This task will specify the end-to-end conceptual architecture of the UPTIME solution. The architecture will be based on middleware solutions combined with appropriate mechanisms for lifting data to a structured and meaningful level, which will enable service adaptation in third party services or self-adjustment of internal UPTIME services.

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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.

"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[7]

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 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 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.

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

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1.2. Technology Intelligence Methodology

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).

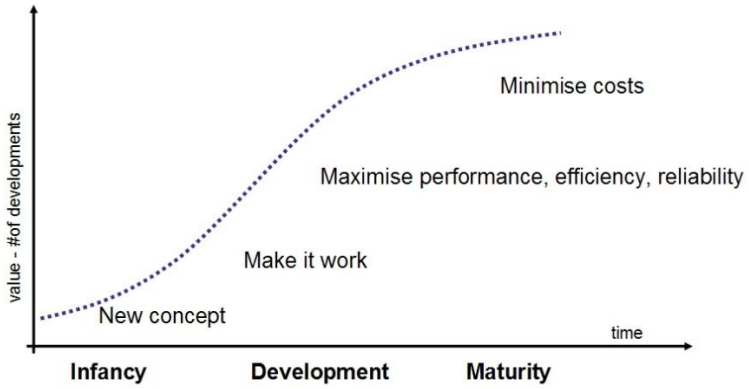

Figure 1: "s" curve of technology evolution

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. Evaluating the UPTIME project within the "s" curve of technology evolution, we can delineate that the project already passed the infancy stage and all efforts of the European consortium are focused on the development phase with the target of "Make it work" and "Maximise performances". This evaluation is not only based on the study of UPTIME project but it is also based on a comparing process with the outputs of the Deliverable 1.1 (patents, literature, etc) that are strictly correlated to the results of the market analysis in D8.1.

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1.3. Links with other deliverables

- Deliverable 1.1 is linked with other deliverables of the project, in particular, Deliverable 1.3 and 1.4.
- Deliverable 1.3 uses D1.1 as founding building for the design of the preliminary UPTIME data model (Figure 2).
- Deliverable 1.4, with the support of the D1.1, will perform a survey on algorithms existing in prototype and industrial predictive maintenance information systems as well as in literature in the areas of Diagnosis, Prognosis and Maintenance Decision Making (Figure 3).

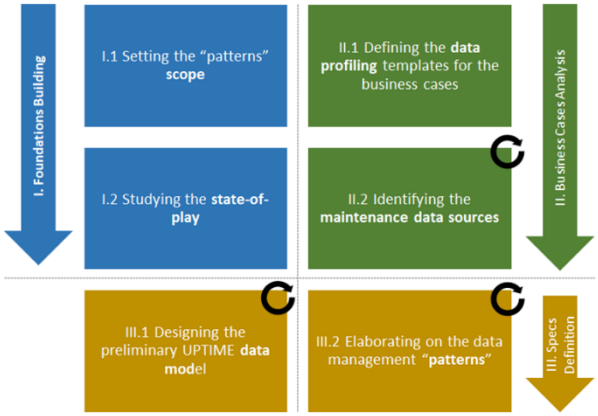

Figure 2: D1.3a Approach

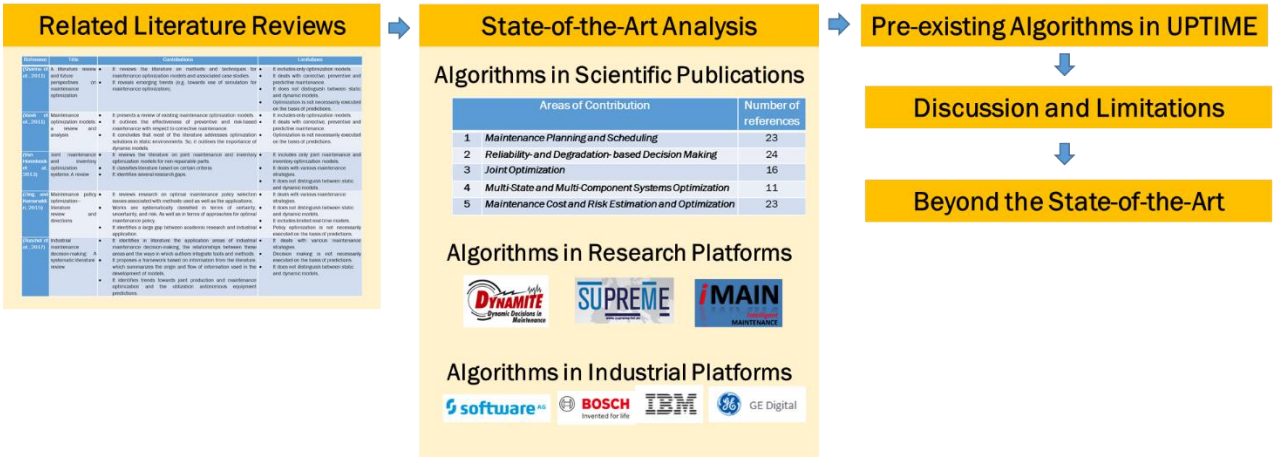

Figure 3: D1.4a Methodology

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2. Analysis of State-of-Play Analysis on PM Models, Techniques & Platforms

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

- KPIs;
- Scientific publications;
- Platforms;
- Patents.

2.1 KPIs Analysis

The state of play presented in the following paragraphs identifies 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.

Most of the KPIs identified in Deliverable 1.1 have been used by business partners in the proposal preparation and confirmed in the requirements analysis. The KPIs are also useful for UPTIME project evaluation (see activities in WP4, WP5, WP6) for the definition of the targets.
Analysed KPIs of this deliverable are relevant to the predictive maintenance sector, they are typical targets achieved with a condition based monitoring technique on machines and equipment, in general, following this technique has an effect on a wide range on aspects of the factory: production performances, maintenance costs and safety.

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 =** $\frac{Parts\ produced \cdot Ideal\ Cycle\ Time}{T_{UP}}$
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	

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	

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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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2.2 Scientific Literature Analysis

Scientific literature offers a wide range of case studies on PM with the possibility to go deeper in a varied topic. Scientific literature was analysed using the most common online search engines to explore, in an exhaustive way, professional databases, academic journals and social networks. In order to obtain a valuable collection of publications for the UPTIME project the research focus was on an integrated solution for predictive maintenance, such as platforms, and with the target on the methodology. The most interesting publications are collected in Appendix A.

The outputs of the scientific literature scouting performed in this deliverable are mainly relevant to platform systems for data acquisition, data management and data processing, when possible, the publication results are supported by case studies; the methodology approach is variable and depending on the author's strategy. In 2009, within European DYNAMITE Project, the University of Lorraine presented a generic prognostic approach for proactive maintenance decision support with the aim to develop a service platform and a global formalization of the process[8]. The University of Milan in 2015 developed and presented a paper with where the PM is the combination of web services and statistical analysis implemented with the Condition Based Maintenance in a manufacturing case study[9]. The development continued and today the platform solutions are several, the University of Bucharest proposes one of these, the method is based on a five-stage approach (IoT, cloud computing, big data analytics, cyber-physical systems and prediction technologies)[10]. To increase the production process quality of manufacturing machines, Slovak University of Technology propose a concept of PM based on Hadoop framework and NoSQL system integrated into a traditional data warehouse system[11].

In conclusion, the literature analysis provides to the UPTIME project and partners a general point of view on the development of integrated solutions by scientific community supported by case study and based on different methodologies but always focused on the predictive maintenance sector.

[8] Voisin & Levrat & Cocheteux & Iung. (2010). Generic prognosis model for proactive maintenance decision support: Application to pre-industrial e-maintenance test bed. Journal of Intelligent Manufacturing. 21.
[9] Fumagalli, Macchi, Integrating maintenance within the production process through a flexible E-maintenance platform, IFAC-PapersOnLine, Volume 48, Issue 3, 2015
[10] Y. 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, July 2017.
[11] Spendla, Lukas & Kebisek, Michal & Pavol, Tanuska & Hrčka, Lukas. (2017). Concept of predictive maintenance of production systems in accordance with industry 4.0.

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2.3 PM Platforms analysis

2.3.1. PM 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 was performed with a focus on the previous FP7 project, H2020 projects (from 2012 onwards) and a summary of the projects belonging to the FoF9 Cluster based on Predictive Maintenance. The results are reported in Appendix B.

The European Commission has paid much attention to financing projects involved in predictive maintenance and connecting a large number of industrial sectors. The objectives of the research projects are aimed at obtaining numerous advantages both in the economic and productive area and in the environmental field.

As in the case of UPTIME project, the projects analysed are firstly focused on the data collection and management of the data provided, for example, by sensors in the production line, with different methodology approach and different sector examined. Secondly, the data collection evolves in an accessible platform with the scope to analyse and to support the industrial partner involved in the project. The maintenance based on the condition monitoring helps, generally, to reduce maintenance costs, improve productivity, reduce the accidents and improve the safety and finally reduce pollution due to not regulated maintenance. UPTIME project is one of the last project started, the time factor is an important advantage to get more statistics from previous projects.

2.3.2. PM Commercial Platforms

Appendix C summarise the potential commercial competitors of the UPTIME E-Maintenance Platform. The collection, that it is massive but not fully exhaustive, was performed with a desktop search and the list was enriched with the input of the Deliverable 8.1 Market Analysis and with the scouting of commercial software relevant to the Predictive Maintenance sector.

The companies, big players or start-ups, involved in the predictive maintenance sector are several but it is not easy to find a wide number of players that offer a full integrated predictive maintenance solution in form of platform as in the case of the UPTIME project. This is due to the fact that the data collection depends on many factors (industry sector, production lines, sensors, data output, etc.) and it is not possible to create a default platform that fits each business. UPTIME is involved in three different sectors with the chance to develop the following three different business and to maintain the same methodology.

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3. 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 growth 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 analysis is based on the Derwent Innovation suite[12], 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) was 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, the keywords used to perform this analysis on Derwent Innovation were:

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 239 INPADOC[13] patent family. In the following figures are reported some data trends concerning the patents dataset analyzed in a geographical area and patents application volume for each year.

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

[13] 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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Figure 4: Top Countries and Territories with a high number of patents deposition

China is the country with the most relevant number of deposited patents (197) this is due to particular attention on this topic paid by several Chinese universities, technology companies and energy sector companies. The United States is following China with 73 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 third place with the deposition of 36 patents about predictive maintenance platform.

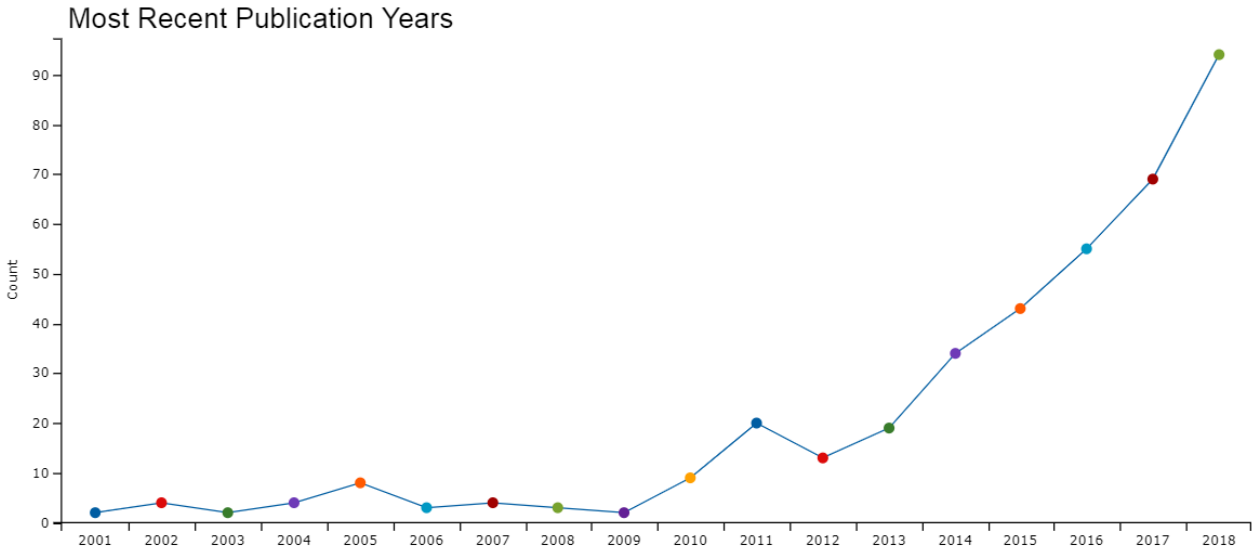

Figure 5: Trend of patents deposition starting from 2001 until 2018

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Before 2009, the number of patents deposited about the topic concerning predictive maintenance was not significant and not always focused on online platforms for “smart monitoring”. Starting from 2010, except for 2012, the number of patents deposited on this topic shows a strong growing trend; this factor is due to a significant interesting on this topic thanks to important technological developments and an economical growing from developing countries of Southeast Asia. In this patent dataset, it is possible to single out a set of interesting keywords describing the main aspects and insights of the selected patents. The principal focus of the patents is the deployment of real-time platforms able to perform online monitoring on industrial equipment; secondly, a focus on the power consumption monitoring, resource managing and processing period is often present, with the aim of minimizing 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.

The patent analysis was updated for the 2nd cycle of the project (M16-18), after a general update with 2018 results, the update was mainly focused on the three Business Case Sectors of the project, and performed with the input of the D8.1 (Market Analysis); the totality of the results is presented in form of relevant patents in Appendix D.

Patents relevant to the three Business Case Sectors of the project are focused on household and domestic appliances and automation in the industrial sector (generic industry, automotive and aircraft), instead, the focus on the steel rolling mill doesn’t generate interesting patents relevant to the UPTIME project. Integrated platforms for domestic appliances described in the analysed patents are based on the collection of machine data information thanks to a risk estimating system unit integrated to profiling the user for the customer service team that can analyse data, predict failures, determinate maintenance, and reduce the energy consumption (EP2612283A1, CN103592919B).

The patents relevant to the industry sector are focused on the monitoring of conveyor idlers and rollers (WO2018141009A1), manufacturing machines (KR1322434B1) and automotive assembly lines (DE102017006141A1). Real-time monitoring of crucial elements and faults diagnosis of these patent cases avoids forced maintenance downtime with a clear improvement in production, operative costs reduction and progress in safety for the operators.

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4. Strategic Intelligence Platform

The Strategic Intelligence is a tailored service proposed by RINA to the companies willing to be continuously updated on the main technological and market trends, technological novelties, their competitive scenario, and on the technology transfer and R&D opportunities relevant for their business.

The output of this service is a web-based platform accessible by a multiple number of users with a user-friendly interface and the contents are produced by experienced and highly skilled analysts.

For the UPTIME project, the website address is: https://uptime.dappolonia-innovation.com/

The web platform is based on Wordpress, a free and open-source content management system (CMS) based on PHP and MySQL. Since it was released in 2003, WordPress has become one of the most popular web publishing platforms. Today it powers nearly 30 percent of the entire web — from hobby blogs to some of the biggest news sites online. The main feature of Wordpress are:

- Flexibility, you can create any type of website you want;
- Publishing Tools, WordPress makes it easy for you to manage your content. Create drafts, schedule publication, and look at your post revisions. Make your content public or private, and secure posts and pages with a password;
- User Management;
- Media Management;
- Full Standards Compliance;
- Easy Theme System;
- Extend with Plugins;
- Built-in Comments;
- Search Engine Optimized;
- Multilingual.

The content of the web platform is organized along five categories:

- ✓ **Market&Players**: main players involved in the business of the predictive maintenance, hardware and software producers, producers or companies which offer integrated solutions
- ✓ **R&D**: European project where Predictive Maintenance is the main subject
- ✓ **IP**: Intellectual properties, interesting patents inherent to the predictive maintenance or relevant to the main player
- ✓ **Publications**: scientific publications

Each area includes, when possible, the following sub-categories, based on a segmentation of the D1.1 output:

- ✓ Tools
- ✓ Data Processing
- ✓ Integrated solutions

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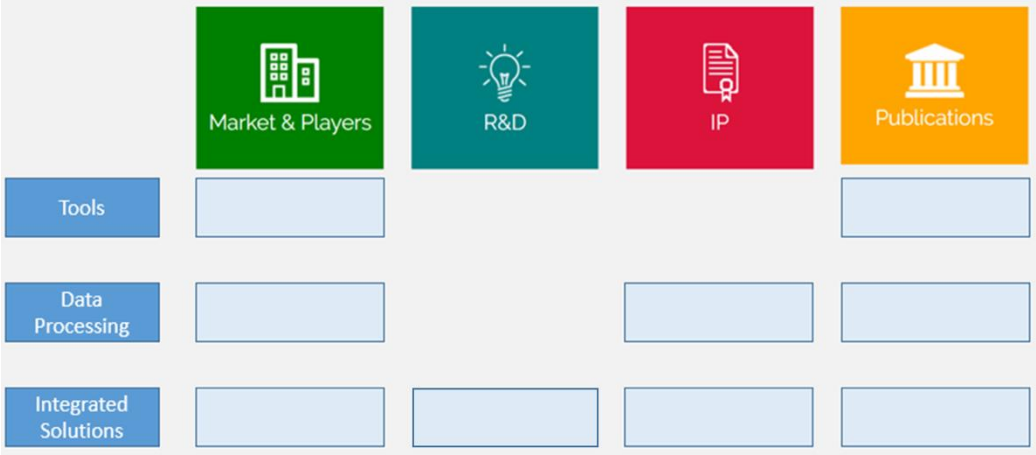

Figure 6: Content categorisation

The focus on R&D category was only on European Consortium Integrated Solutions because these financed projects are the main UPTIME competitors. The focus on intellectual properties was only on Data Processing and Integrated Solutions topics to obtain more relevant results.

The homepage structure foresees a header on top, a slider showing a preview of the platform guidelines, the main content organized vertically in 4 columns corresponding to 4 categories (Market&Players, R&D, IP and Publications), and a footer.

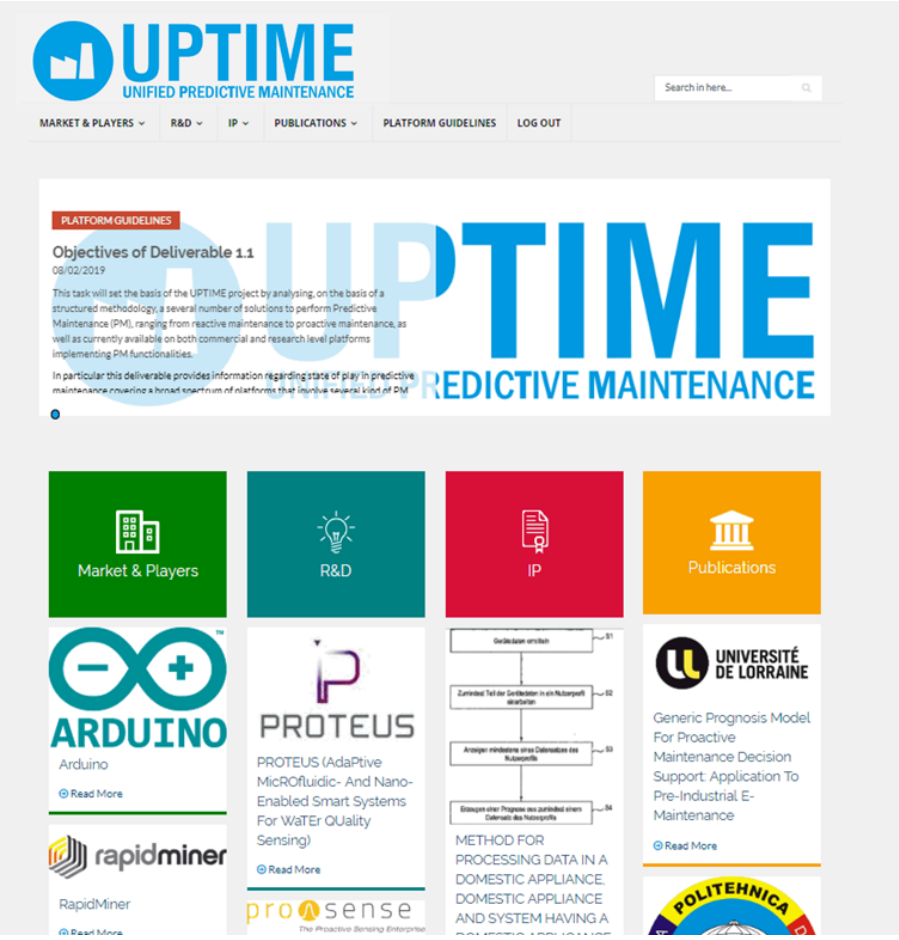

Figure 7: Homepage structure

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The four columns show short previews (picture and title) of up to five recent posts belong to the 4 categories Market&Players, R&D, IP and Publications. This structure allows catching a first glimpse of the latest contents and developments.

It is possible to access the archive of all posts belonging to a category by clicking on the column header or by clicking on the category name in the top menu to visualize the sub-subject (Tools, Data Processing, Integrated Solutions).

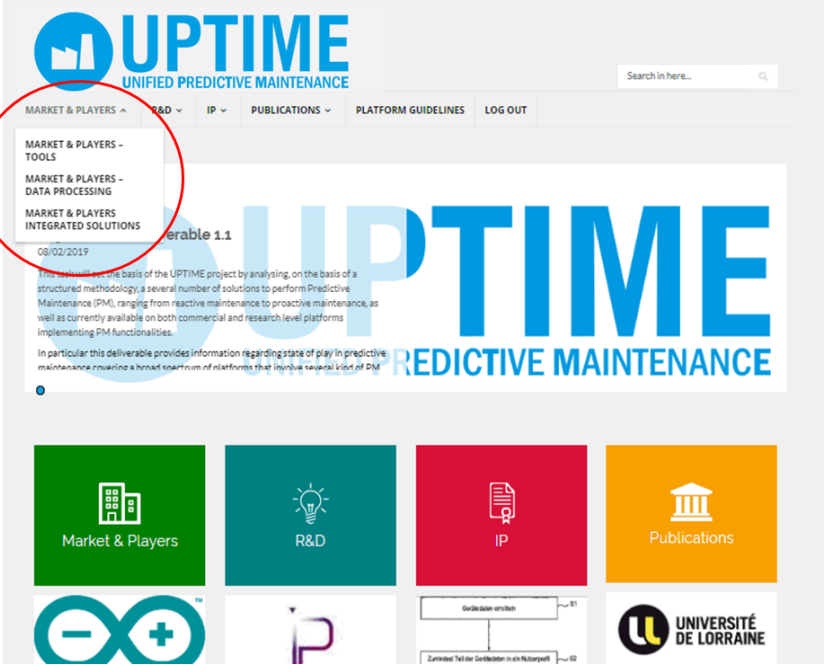

Figure 8: Platform sub-subject browsing

By clicking on each sub-subject in the header bar is possible to find each post relevant to that subject (to see the following screenshot).

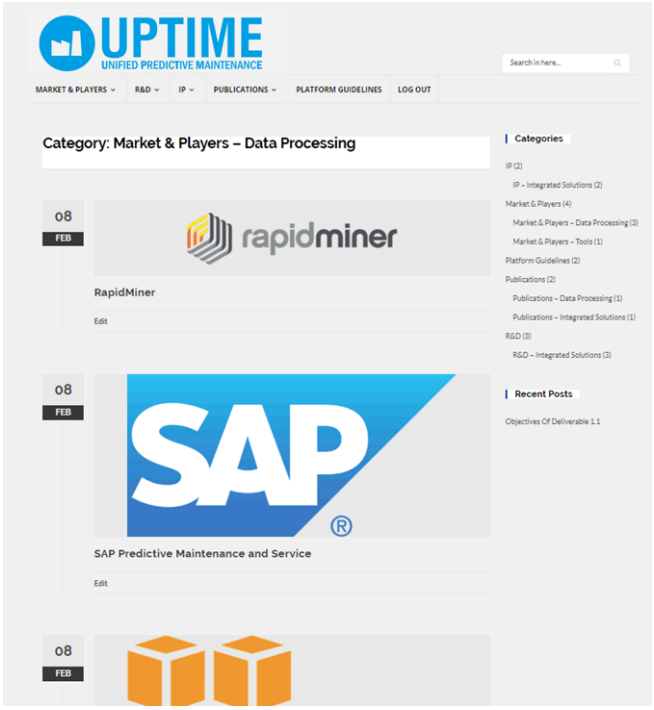

Figure 9: Platform browsing

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For each page, there will be a focusing page with the result of the D1.1. Each page is focused on the specific argument.

Platform Guidelines (by clicking on the top header bar) features posts relevant to the world of Predictive Maintenance (KPI, objectives of the deliverable, and methodology) and relevant to the UPTIME project.

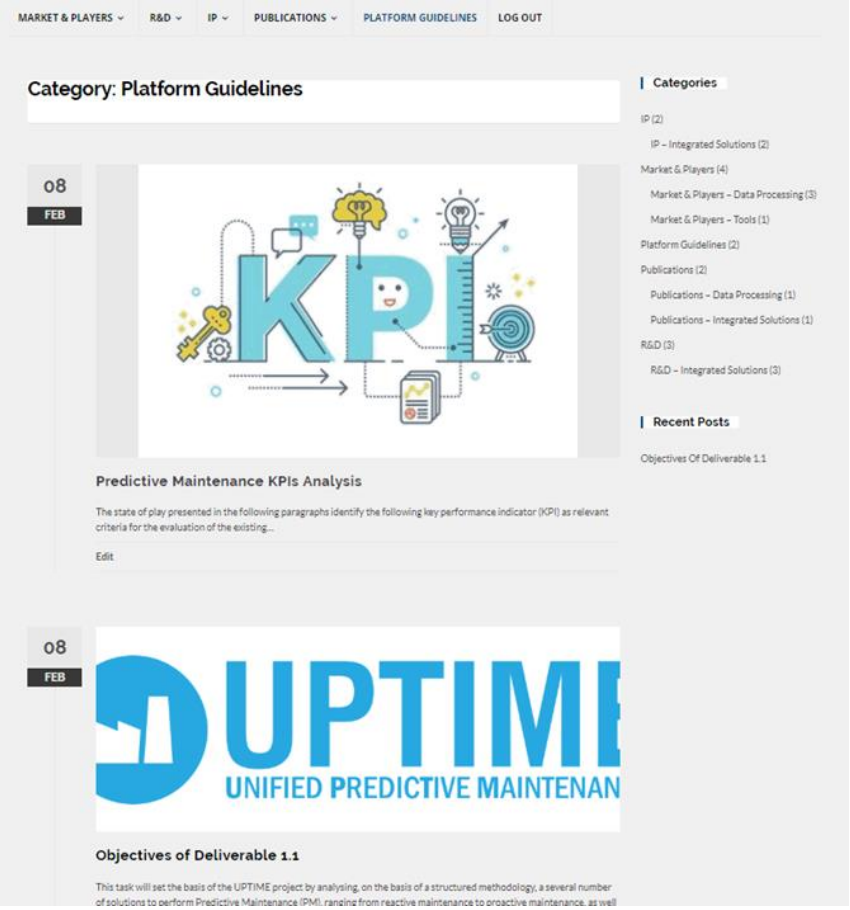

Figure 10: Platform Guidelines

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5. Conclusion and Outlook

At the end of this deliverable, looking at the "State-of-Play Analysis on Predictive Maintenance Models, Techniques & Platforms" of the UPTIME Project, it was possible to identify its position on the curve of technology evolution as in the development phase. The project already passed the infancy stage and all efforts of the European consortium are focused on the development phase with the target on the maximisation and implementation of the performances. This evaluation is not only based on the study of UPTIME project but it is also based on a comparing process with the outputs of the Deliverable 1.1 (patents, literature, etc) that are strictly correlated to the results of market analysis in D8.1. This result is supported by the trend of patent deposition that identifies growth in the number of patents starting from 2010. In the collected patent dataset it's possible to individuate a set of interesting keywords and results describing the main aspects and insights of the selected patents.

The main field where the analysed patents are oriented is the deployment of real-time platforms able to perform online monitoring on industrial equipment, secondly, a focus on the power consumption monitoring, resource managing and processing period is often present, with the aim of minimizing 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. In this framework, the UPTIME project, that will deploy e-maintenance services and tools for industry sector, it is fully in line with the market demands and trends of sector thanks to clear objectives focused on the implementation and unification of system information addressing the predictive maintenance strategy.

The output and content of Deliverable 1.1 (commercial and R&D active players, relevant intellectual properties and scientific publications) is a web-based platform with public access and with a user-friendly interface to visualize and analyse the contents on the State-of-Play of the Predictive Maintenance.

For the UPTIME project, the web-based platform site address is:
https://uptime.dappolonia-innovation.com/

In conclusion, analysing the activities carried out in this deliverable, they highlight a considerable interest in the field of predictive maintenance encouraging the development of the UPTIME project and of all those projects involved in the FoF09 cluster.

Predictive maintenance is certainly an evolving topic that every day involves a greater number of big players to provide turnkey solutions, such as online platform, to end customers to improve all key performance indicators.

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APPENDIX A - Scientific Literature

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.	

Generic prognosis model for proactive maintenance decision support: Application to pre-industrial e-maintenance	
TITLE: Generic prognosis model for proactive maintenance decision support: Application to pre-industrial e-maintenance	**ABSTRACT:** Proactivity in maintenance, which is mainly materialized by degradation-based anticipation, becomes essential to avoid failure situation with negative impact on product and/or system conditions. It leads to make emerging the E-maintenance philosophy to move from “fail and fix” maintenance practices to “predict and prevent” strategies. Within these new strategies, the anticipation action is fully supported by prognosis business process. Indeed it analyses the degradation impact on the component itself but also on the global performances of the production system in order to predict future failures of the system and investigate (future maintenance) actions. However, only few research works focuses on generic and scalable prognostic approach. Existingmethods are generally restricted on component view and for solving the failure prediction issue. Consequently, the contribution presented in this paper aims at developing a global formalization of the generic prognosis business process. This generic process can be used after, from an instantiation procedure, to develop specific prognosis processes related to particular application such as shown in this paper with the case of E-maintenance platform developed within DYNAMITE Project.
AUTHOR(S): Alexandre Voisin, Eric Levrat, Pierre Cocheteux, Benoît Iung.	
AFFILIATION: University of Lorraine, France	
PUBBLICATION YEAR: 2009	
JOURNAL: Journal of Intelligent Manufacturing, Springer Verlag (Germany), 2009, 21 (2), pp.177-193.	

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	

An arduino platform for remote control and bus testing of programmable instruments	
TITLE: An arduino platform for remote control and bus testing of programmable instruments	**ABSTRACT:** This paper presents an Arduino platform developed to control a programmable instrument (a digital signal generator) remotely through the RS-232 interface using the Standard Commands for Programmable Instruments (SCPI). The platform can be used in Automatic Testing laboratories, where manual control of instruments is not possible or it can be dangerous for human or when the testing scenario must be repeated several times. Also, the developed Arduino platform can be used to generate data traffic through the RS-232 bus for the bus health testing from a predictive maintenance point-of-view, the platform being much cheaper than classical bus testing demo boards from leading companies. Finally, the platform can be easily extended with different interfaces or shields for other data buses like RS-485, USB, Ethernet, CAN, etc., and for other test and measurement instruments.
AUTHOR(S): Elena Daria Tica, Lucian Andrei Perișoara, Pavol Tanuska, Alexandru Vasile.	
AFFILIATION: University Politehnica of Bucharest, Romania	
PUBBLICATION YEAR: 2017	
JOURNAL: IEEE Xplore: 16 January 2017	

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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.	

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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APPENDIX B – Predictive Maintenance Platforms Developed in EU R&D Projects

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: 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)	
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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NAME: Z-BRE4K (a novel predictive maintenance platform to eliminate unexpected-breakdowns and extend the life of production systems.)	
PRODUCER: European Consortium	
CATEGORY: Platform	
REFERENCES: https://www.z-bre4k.eu/ ASOCIACION DE INVESTIGACION METALURGICA DEL NOROESTE info@z-bre4k.eu https://cordis.europa.eu/project/rcn/211380/factsheet/en	
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: Maintenance in general and predictive maintenance strategies in particular should now face very significant challenges to deal with the evolution of the equipment, instrumentation and manufacturing processes they should support. Preventive maintenance strategies designed for traditional highly repetitive and stable mass production processes based on predefined components and machine behaviour models are no longer valid and more predictive-prescriptive maintenance strategies are needed.

The Z-Break solution comprises the introduction of eight (8) scalable strategies at component, machine and system level targeting (1) the prediction occurrence of failure (Z-PREDICT), (2) the early detection of current or emerging failure (Z-DIAGNOSE), (3) the prevention of failure occurrence, building up, or even propagation in the production system (Z-PREVENT), (4) the estimation of the remaining useful life of assets (Z-ESTIMATE), (5) the management of the aforementioned strategies through event modelling, KPI monitoring and real-time decision support (Z-MANAGE), (6) the replacement, reconfiguration, re-use, retirement, and recycling of components/assets (Z-REMEDIATE), (7) synchronizing remedy actions, production planning and logistics (Z-SYNCHRONISE), (8) preserving the safety, health, and comfort of the workers (Z-SAFETY).

Z-Bre4k impact to the European manufacturing industry and the society can be summarised in the following: (i) increase of the in-service efficiency by 24%, (ii) reduced accidents, (iii) increased Verification according to objectives, (iv) 400 new jobs created and (v) over €42M ROI for the consortium.

To do that we have brought together a total of seventeen (17) EU-based partners, representing both industry and academia, having ample experience in cutting-edge technologies and active presence in the EU manufacturing.

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NAME: SERENA (VerSatilE plug-and-play platform enabling remote pREdictive mainteNAnce.)	
PRODUCER: European Consortium	
CATEGORY: Platform	
REFERENCES: https://www.serena-project.eu/ COMAU S.p.A. - Project coordinator it@lms.mech.upatras.gr https://cordis.europa.eu/project/rcn/211752/factsheet/en	
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: The growing complexity of modern engineering systems and manufacturing processes is an obstacle to concept and implement Intelligent Manufacturing Systems (IMS) and keep these systems operating at high levels of reliability. Additionally, the number of sensors and the amount of data gathered on the factory floor constantly increases. This opens the vision of truly connected production processes where all machinery data are accessible allowing easier maintenance of them in case of unexpected events. SERENA project will build upon these needs for saving time and money, minimizing the costly production downtimes. The proposed solutions are covering the requirements for versatility, transferability, remote monitoring and control by a) a plug-and-play cloud based communication platform for managing the data and data processing remotely, b) advanced IoT system and smart devices for data collection and monitoring of machinery conditions, c) artificial intelligence methods for predictive maintenance (data analytics, machine learning) and planning of maintenance and production activities, d) AR based technologies for supporting the human operator for maintenance activities and monitoring of the production machinery status. SERENA represents a powerful platform to aid manufacturers in easing their maintenance burdens and for this purpose will be applied in different applications. More specifically, SERENA project will focus on advancing the TRL of the existing developments into levels TRL5 to TRL7. For this purpose, SERENA consortium will fully demonstrate the proposed approach in different industrial areas (white goods, metrological engineering and elevators production) and investigate applicability in steel parts production industry (extended-demonstration activities) checking the link to other industries (automotive, aerospace etc.) showing the versatile character of the project.

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NAME: Programs (PROGnostics based Reliability Analysis for Maintenance Scheduling)	
PRODUCER: European Consortium	
CATEGORY: Platform	
REFERENCES: https://www.programs-project.eu/ Fidia S.p.A. - Project coordinator Raffaele Ricatto - r.ricatto@fidia.it https://cordis.europa.eu/project/rcn/211298/factsheet/it	
KEYWORDS: predictive maintenance,prognostics method, data analysis, FMECA, PRM	**BUSINESS SECTOR AND EVALUATION:** Advanced e-maintenance solution for industrial sector
KEY PERFORMANCE INDICATOR (if possible): Mean Time Between Failure (MTBF), Mean Time To Repair (MTTR),	**PRICE:** n/a

DESCRIPTION: The main objectives of this project are to develop a model-based prognostics method integrating the FMECA and PRM approaches for the smart prediction of equipment condition, a novel MDSS tool for smart industries maintenance strategy determination and resource management integrating ERP support, and the introduction of an MSP tool to share information between involved personnel. The proposers' approach is able to improve overall business effectiveness with respect to the following perspectives:

- Increasing Availability and then Overall Equipment Effectiveness through increasing of MTBF, and reduction of MTTR and MDT.
- Continuously monitoring the criticality of system components by performing/updating the FMECA analysis at first implementation or whenever a variation in the system design or composition occurs.
- Building physical-based models of the components which have a higher criticality level or which status is difficult to monitor.
- Determining an optimal strategy for the maintenance activities.
- Creating a new schedule for the production activities that will optimize the overall system performance through a Smart Scheduling tool ensuring collaboration among the MDSS, the ERP and the RUL Estimation tool.
- Providing, in addition to traditional data acquisition and management functions in a machine condition monitoring system, robust and customizable data analysis services by a cloud-based platform.
- An Intra Factory Information Service will be developed to allow the company staff to be quickly informed of changes in the machine tool performances and to easily react to eventual production and maintenance activities rescheduling.

The production and maintenance schedule of complete production lines and entire plants will run with real-time flexibility in order to perform at the required level of efficiency, optimize resources and plan repair interventions.

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NAME: PreCoM (Predictive Cognitive Maintenance decision-support system)	
PRODUCER: European Consortium	
CATEGORY: Platform	
REFERENCES: https://www.precom-project.eu/ Linnaeus University - Project coordinator Francesco Barbabella, Ph.D. - francesco.barbabella@lnu.se https://cordis.europa.eu/project/rcn/211729/factsheet/en	
KEYWORDS: predictive maintenance,predictive cognitive maintenance decision-support, data acquisition	**BUSINESS SECTOR AND EVALUATION:** Advanced e-maintenance solution for industrial sector
KEY PERFORMANCE INDICATOR (if possible): overall equipment effectiveness, percentage of predictive maintenance execution	**PRICE:** n/a

DESCRIPTION: Cheaper and more powerful sensors, together with big data analytics, offer an unprecedented opportunity to track machine-tool performance and health condition. However, manufacturers only spend 15% of their total maintenance costs on predictive (vs reactive or preventative) maintenance.
The project will deploy and test a predictive cognitive maintenance decision-support system able to identify and localize damage, assess damage severity, predict damage evolution, assess remaining asset life, reduce the probability of false alarms, provide more accurate failure detection, issue notices to conduct preventive maintenance actions and ultimately increase in-service efficiency of machines by at least 10%.
The platform includes 4 modules: 1) a data acquisition module leveraging external sensors as well as sensors directly embedded in the machine tool components, 2) an artificial intelligence module combining physical models, statistical models and machine-learning algorithms able to track individual health condition and supporting a large range of assets and dynamic operating conditions, 3) a secure integration module connecting the platform to production planning and maintenance systems via a private cloud and providing additional safety, self-healing and self-learning capabilities and 4) a human interface module including production dashboards and augmented reality interfaces for facilitating maintenance tasks.
The consortium includes 3 end-user factories, 3 machine-tool suppliers, 1 leading component supplier, 4 innovative SMEs, 3 research organizations and 3 academic institutions. Together, we will validate the platform in a broad spectrum of real-life industrial scenarios (low volume, high volume and continuous manufacturing). We will also demonstrate the direct impact of the platform on maintainability, availability, work safety and costs in order to document the results in detailed business cases for widespread industry dissemination and exploitation.

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NAME: PROPHESY (Platform for rapid deployment of self-configuring and optimized predictive maintenance services)	
PRODUCER: European Consortium	
CATEGORY: Platform	
REFERENCES: http://prophesy.eu/ INTRASOFT INTERNATIONAL SA - Project coordinator https://cordis.europa.eu/project/rcn/211300/factsheet/en	
KEYWORDS: predictive maintenance, machine learning, data acquisition, real-time, FMECA	**BUSINESS SECTOR AND EVALUATION:** Advanced e-maintenance solution for industrial sector
KEY PERFORMANCE INDICATOR (if possible): overall equipment effectiveness, percentage of predictive maintenance execution	**PRICE:** n/a

DESCRIPTION: The advent of Industrie4.0 provides opportunities for adopting predictive maintenance (PdM), which represents the ultimate maintenance vision for manufacturers and machine vendors. Nevertheless, there are still barriers to successful deployment including the issues of data fragmentation, limited data interoperability, poor deployment of advanced analytics and lack of effective integration with other systems at the enterprise and field levels. PROPHESY will deliver and validate (in two complex demonstrators) in real plants a PdM services platform, which will alleviate these issues based on the following innovations:

- A CPS platform optimized for PdM activities (PROPHESY-CPS), which will enable maintenance driven real-time control, large scale distributed data collection and processing, as well as improved production processes driven by maintenance predictions and FMECA activities.
- Novel Machine Learning and Statistical Data processing techniques for PdM (PROPHESY-ML), which will be able to identify invisible patterns associated with machine degradation and assets depreciation, while at the same time using them to optimize FMECA activities.
- Visualization, knowledge sharing and augmented reality (AR) services (PROPHESY-AR), which will enable remotely supported maintenance that can optimize maintenance time and costs, while increasing the safety of maintenance tasks.
- A PdM service optimization engine (PROPHESY-SOE), which will enable composition of optimal PdM solutions based on the capabilities provided by PROPHESY-CPS, PROPHESY-ML and PROPHESY-AR. Service optimization aspects will consider the whole range of factors that impact PdM effectiveness (e.g., OEE, EOL, MTBF and more).

PROPHESY will establish and expand an ecosystem of PdM stakeholders around the PROPHESY-SOE, which will serve as a basis for the wider update of the project's results, as it will offer to the CPS manufacturing community access to innovative, turn-key solutions for PdM operations.

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NAME: MANTIS (Cyber Physical System based Proactive Collaborative Maintenance)	
PRODUCER: European Consortium	
CATEGORY: Platform	
REFERENCES: http://www.mantis-project.eu/ MONDRAGON GOI ESKOLA POLITEKNIKOA JOSE MARIA ARIZMENDIARRIETA S COOP - Project coordinator https://cordis.europa.eu/project/rcn/198079/factsheet/en	
KEYWORDS: predictive maintenance,predictive cognitive maintenance decision-support, data acquisition	**BUSINESS SECTOR AND EVALUATION:** Advanced e-maintenance solution for industrial sector
KEY PERFORMANCE INDICATOR (if possible): overall equipment effectiveness, percentage of predictive maintenance execution	**PRICE:** n/a

DESCRIPTION: The overall concept of MANTIS is to provide a proactive maintenance service platform architecture based on Cyber Physical Systems that allows to estimate future performance, to predict and prevent imminent failures and to schedule proactive maintenance. Maintenance is no longer a necessary evil that costs what it costs, but an important function that creates additional value in the business process as well as new business models with a stronger service orientation. Physical systems (e.g. industrial machines, vehicles, renewable energy assets) and the environment they operate in, are monitored continuously by a broad and diverse range of intelligent sensors, resulting in massive amounts of data that characterise the usage history, operational condition, location, movement and other physical properties of those systems. These systems form part of a larger network of heterogeneous and collaborative systems (e.g. vehicle fleets or photovoltaic and windmill parks) connected via robust communication mechanisms able to operate in challenging environments. MANTIS consists of distributed processing chains that efficiently transform raw data into knowledge while minimising the need for bandwidth. Sophisticated distributed sensing and decision making functions are performed at different levels in a collaborative way, ranging from local nodes to locally optimise performance, bandwidth and maintenance; to cloud-based platforms that integrate information from diverse systems and execute distributed processing and analytics algorithms for global decision making. The research addressed in MANTIS will contribute to companies' assets availability, competitiveness, growth and sustainability. Use cases will be the testing ground for the innovative functionalities of the proactive maintenance service platform architecture and for its future exploitation in the industrial world. Results of MANTIS can be utilised directly in several industry areas and different fields of maintenanance.

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NAME: ProaSense: The Proactive Sensing Enterprise	
PRODUCER: European Consortium	
CATEGORY: Platform	
REFERENCES: http://www.proasense.eu/ STIFTELSEN SINTEF - Project coordinator Dr. Hans Torvatn - hans.torvatn@sintef.no https://cordis.europa.eu/project/rcn/110728/factsheet/en	
KEYWORDS: Proactive Enterprise Systems, Situational Awareness, Big Data, Scalable Storage, Smart Sensing Services, Proactive Manufacturing, Proactive monitoring	**BUSINESS SECTOR AND EVALUATION:** Advanced e-maintenance solution for industrial sector
KEY PERFORMANCE INDICATOR (if possible): overall equipment effectiveness, percentage of predictive maintenance execution	**PRICE:** n/a

DESCRIPTION: A new class of enterprise systems, proactive enterprises, that will be continuously aware of that what "might happen" in the relevant business context and optimize their behavior to achieve that what "should be the best action", are emerging nowadays. ProaSense's core goal in this context is to pave the way for an efficient transmission from Sensing into Proactive enterprises. By being one of early adopters in this shift from a reactive to the proactive computing, we expect that the results from this project will have a considerable impact on developing new class of systems that will be in essence of a world where it is possible to prevent problems or capitalize on opportunities before they even occur. Beside scientific and technical excellence, several other mechanisms will be applied for ensuring such an impact.

This will be achieved through the adoption of the Observe-Orient-Decide-Act (OODA) loop of situational awareness and development of corresponding technologies supporting a scalable, distributed architecture for the management and processing of big-data that will eventually enable continuous monitoring and the need for service adaptation and propose corresponding changes in an (semi-) automatic way. Key innovations include novel approaches for scalable storage and access to sensed data; development of smart sensing services, services for anticipation management, approaches for probabilistic stream processing and goal-driven Complex Event Processing. The project will validate the ProaSense approach in two key areas: proactive manufacturing in the area of production of lighting equipment, and proactive monitoring services within the oil and gas sector.

A consortium of 2 large industry partners, 1 SME and 5 research organizations from 6 European countries provides the necessary technological and scientific competencies and assures the exploitation of the developed technology.

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NAME: PROTEUS (AdaPtive micROfluidic- and nano-enabled smart systems for waTEr qUality Sensing)	
PRODUCER: European Consortium	
CATEGORY: Platform	
REFERENCES: https://www.proteus-bigdata.com/ INSTITUT FRANCAIS DES SCIENCES ET TECHNOLOGIES DES TRANSPORTS, DE L'AMENAGEMENT ET DES RESEAUX - Project coordinator https://cordis.europa.eu/project/rcn/194252/factsheet/en	
KEYWORDS: Proactive Enterprise Systems, Situational Awareness, Big Data, Scalable Storage, Smart Sensing Services, Proactive Manufacturing, Proactive monitoring	**BUSINESS SECTOR AND EVALUATION:** Advanced e-maintenance solution for industrial sector
KEY PERFORMANCE INDICATOR (if possible): overall equipment effectiveness, percentage of predictive maintenance execution	**PRICE:** n/a
DESCRIPTION: Water management requires massive, low-cost monitoring means coping with differentiated and evolving requirements. However, the majority of multifunctional water sensors only supports predefined goals hindering interoperability, with a high cost, impeding large scale deployments. Addressing this, PROTEUS aims at offering x10 reduction in both size and unit function cost compared to state of the art. To this end, an increased number of functions will be integrated at a reduced cost and PROTEUS will deliver a reconfigurable microfluidic-and nano-enabled sensor platform for cognitive water quality monitoring. Innovative embedded software will provide reconfigurability of the sensing board to support several differentiated applicative goals while cognitive capabilities will manage evolving requirements during exploitation. Energy autonomy will be made by harvesting water flow energy. In addition, low cost of additional sensing components will enable redundancy increasing life span of the systems. The main challenge relates to the heterogeneous integration into a monolithic, microfluidic sensing chip of carbon-nanotubes-based resistive chemical sensors, of MEMS physical and rheological resistive sensors and of a multifunctional adaptive deep-submicron CMOS system on chip. Upstream, high level system design addressing industrial use cases, manufacturability and cost-effectiveness, packaging, energy budget and interfaces between building blocks, will enable consistency and efficiency of the whole approach. Downstream, system validation will be carried out at different levels: benchmarking, reliability assessment to guarantee service time, model deployments and field testing. The consortium brings together renowned actors along the whole value chain, including system integration and end users. This will contribute to post-project exploitation prepared by ensuring appropriate inclusion of business requirements within the system design.	

NAME: TOREADOR (TrustwOrthy model-awaRE Analytics Data platfORm)	
PRODUCER: European Consortium	
CATEGORY: Platform	
REFERENCES: http://toreador-project.eu	
KEYWORDS: continuous monitoring, Big Data Analytics, , Proactive Manufacturing, Proactive monitoring	**BUSINESS SECTOR AND EVALUATION:** Advanced e-maintenance solution for industrial sector
KEY PERFORMANCE INDICATOR (if possible): overall equipment effectiveness, percentage of predictive maintenance execution	**PRICE:** n/a
DESCRIPTION: Many companies and organisations in Europe have become aware of the potential competitive advantage they could get by timely and accurate Big Data analytics, but lack the IT expertise and budget to fully exploit BDA. To overcome this hurdle, TOREADOR takes a model-based BDA-as-a-service (MBDAaaS) approach, providing models of the entire Big Data analysis process and of its artefacts. TOREADOR open, suitablefor-standardisation models will support substantial automation and commoditisation of Big Data analytics, while enabling it to be easily tailored to domain-specific customer requirements. Besides models for representing all aspects of BDA, TOREADOR will deliver an architectural framework and a set of components for model-driven set-up and management of Big Data analytics processes. Once TOREADOR MBDAaaS will become widespread, price competition on Big Data services will ensue, driving costs of Big Data analytics well within reach of EU organizations (including SMEs) that do not have either in-house Big Data expertise or budget for expensive data consultancy.	

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APPENDIX C – Predictive Maintenance Commercial Platforms

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: 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

NAME: BRAINCUBE	
PRODUCER: Braincube	
CATEGORY: Platform	
REFERENCES: https://braincube.com/	
KEYWORDS: continuous monitoring, Big Data Analytics, performance indicators , efficency monitoring	**BUSINESS SECTOR AND EVALUATION:** Advanced e-maintenance solution for industrial sector
KEY PERFORMANCE INDICATOR (if possible): OVERALL EQUIPMENT EFFECTIVENESS, MEAN TIME BETWEEN FAILURE	**PRICE:** n/a

DESCRIPTION: Braincube is a one-of-a-kind solution that maximizes your productivity.
Braincube AI technologies continuously collect your data in any format and structure it in a single, secure database and provide production teams with optimal equipment control settings. Braincube is a software company and a pioneer in artificial intelligence solutions for the manufacturing industry. Founded in 2007 by three engineers, Hélène Olphe-Galliard, Sylvain Rubat du Mérac and Laurent Laporte, it is established in Issoire, France. Braincube supports the digital transformation of its industrial customers and improves their manufacturing performance through its unique big data and artificial intelligence solution. It helps world-class manufacturers connect their factories, optimize their process operations through predictive algorithms and turn them into smart and autonomous factories. The company's products have already been adopted in over 200 manufacturing sites based in 30 countries across 4 continents. Braincube supports industrial leaders in various verticals: paper (UPM, Smurfit Kappa), steel (ArcelorMittal, Gerdau), chemicals (The Dow Chemical Company, Clariant), automotive (PSA, Plastic Omnium), food (Nestlé, Avril), building products (Saint-Gobain, GAF).

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NAME: Fives Maintenance	
PRODUCER: Fives Maintenance	
CATEGORY: Platform and maintenance	
REFERENCES: https://www.fivesgroup.com/	
KEYWORDS: Industrial AI, IoT,continuous monitoring, Big Data Analytics, performance indicators , advanced analytics	**BUSINESS SECTOR AND EVALUATION:** Advanced e-maintenance solution for industrial sector
KEY PERFORMANCE INDICATOR (if possible): OVERALL EQUIPMENT EFFECTIVENESS, MEAN TIME BETWEEN FAILURE	**PRICE:** n/a
DESCRIPTION: Fives is an industrial engineering group with an extensive multi-sector expertise. Its particularity lies in the fact that it is organized in human-sized companies, each specialist in their market, whether geographical or technological. Fives believes in this strategy which promotes a sense of initiative, a strong understanding of its customers, technical excellence and team spirit. All these shared values are now promoted under a unique international brand: Fives. Fives provides high added-value solutions and equipment for the world's largest industrial players. As a designer and a manufacturer, Fives has its own proprietary technologies and supplies machines, process equipment, complete production lines and process units. The multisector commercial offer of Fives is presented through 19 business lines, specialized by market or technology. Each business line includes design, supply, installation, service and maintenance.	

NAME: Nokia Asset Analytics	
PRODUCER: Nokia	
CATEGORY: Platform	
REFERENCES: https://spacetimeinsight.com/warp-6/	
KEYWORDS: Industrial AI, IoT,continuous monitoring, Big Data Analytics, performance indicators , advanced	**BUSINESS SECTOR AND EVALUATION:** Advanced e-maintenance solution for industrial sector
KEY PERFORMANCE INDICATOR (if possible): OVERALL EQUIPMENT EFFECTIVENESS, MEAN TIME	**PRICE:** n/a
DESCRIPTION: Nokia Asset analytics helps asset-intensive companies extend the life of their assets and optimize operations by determining the health, criticality, and risk of failure of assets to help make informed, risk-based and return-based decisions. Nokia Asset Analytics provides a summary of what happened, usually for a set of predefined periods and other attributes. Useful for reviewing historical performance and understanding areas for operational improvement. Nokia Asset Analytics identifies why, when, and where something happened, commonly to determine the root cause of an operational failure or unexpected event. Useful for identifying effective remediation alternatives. Nokia Asset Analytics Identifies a probable outcome based on assessing past behavior and likely operating conditions in the future. Useful for taking preventative measures, estimating remaining useful life, and reducing the impact of unplanned events, theft, and other scenarios. Nokia Asset Analytics Identifies specific actions to optimize processes, routes, schedules, and plans. Useful for planning under uncertain conditions, scheduling and positioning resources, and determining the most cost-effective routes.	

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NAME: Predictive Asset Analytics	
PRODUCER: Schneider Electric (FRA)	
CATEGORY: Data Analytics platform	
REFERENCES: https://download.schneider-electric.com/files?p_enDocType=Brochure&p_File_Na	
KEYWORDS: platform, data analysis, predictive maintenance, predictive asset analytics	**BUSINESS SECTOR AND EVALUATION:**
KEY PERFORMANCE INDICATOR (if possible): n/a	**LICENSE:** Payment

DESCRIPTION: Predictive Asset Analytics is a predictive asset analytics solution based on a proprietary algorithm called OPTiCS that uses Advanced Pattern Recognition (APR) and machine learning technology. Predictive Asset Analytics learns an asset's unique operating profile during all loading, ambient and operational process conditions. Existing machinery sensor data is input into the software's advanced modeling process and compared to real-time operating data to determine and alert upon subtle deviations from expected equipment behavior. Once an issue has been identified, the software can assist in root cause analysis and provide fault diagnostics to help the user understand the reason and significance of the problem.
Predictive Asset Analytics predictive asset analytics software makes reliability, performance and efficiency goals more achievable by allowing the user to address issues before they become problems that significantly impact operations. With continuous maintenance and reliability improvements, additional benefits can be achieved. Unscheduled downtime can be reduced because personnel receive early warning notifications of developing issues. Instead of shutting down equipment immediately, the situation can be assessed for more convenient outcomes. Maintenance costs can also be reduced due to better planning; parts can be ordered and shipped without rush
and equipment can continue running. With predictive analytics, personnel know and understand the actual and expected performance for an asset's current operational state. They know where inefficiencies are and their impact on financial performance and can use this information to understand the impact of performance deficiencies on current and future operations. This information also helps assess the risk and potential consequences associated with each monitored asset and can be used to better prioritize capital and operational expenditures. Another increasingly important benefit is the capability for knowledge capture and transfer. Predictive Asset Analytics ensures that maintenance decisions and processes are repeatable even when organizations are faced with transitioning workforces.

NAME: eMaint - CMMS Software	
PRODUCER: Fluke Corporation (USA)	
CATEGORY: Data Analytics platform	
REFERENCES: https://www.emaint.com/cmms-features-benefits/	
KEYWORDS: platform, data analysis, predictive maintenance, condition-based maintenance tool	**BUSINESS SECTOR AND EVALUATION:**
KEY PERFORMANCE INDICATOR (if possible): n/a	**LICENSE:** Payment, free demo available

DESCRIPTION: A Computerized Maintenance Management System (CMMS), also known as Enterprise Asset Management (EAM) software, is designed to help schedule, plan, manage and track maintenance activities associated with equipment, vehicles or facilities.

A CMMS solution provides a central storage location for the majority of data and information for your assets. It manages and controls your work and materials management and parts usage processes. It also tracks maintenance activity over the life cycle of an asset.

Maintenance, facilities and operations departments can use a CMMS to manage assets, work orders, work requests, preventive maintenance tasks, inventory and parts, condition monitoring and maintenance schedules. All maintenance activities can be monitored and analyzed through robust CMMS reporting and dashboard tools.
eMaint delivers ground-breaking asset reliability platforms that will help organizations increase uptime with a seamless integration of maintenance tools and software solutions.

The power of eMaint's CMMS software, combined with Fluke's world-renowned testing and calibration equipment, offers the opportunity to unlock even greater solutions. With Fluke and eMaint, customers have even greater power to simplify complex workflows.
Within eMaint's CMMS system, you can work the way you want to work without feeling constrained by your software. Fluke understands that every industry, company and department are different – you use different terminology, have different processes in place, comply to different regulations, and so on.

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NAME: Amazon Machine Learning	
PRODUCER: Amazon (USA)	
CATEGORY: Cloud platform for machine learning and predictive analysis	
REFERENCES: https://aws.amazon.com/it/machine-learning/	
KEYWORDS: machine learning, cloud, predictive maintenance	**BUSINESS SECTOR AND EVALUATION:**
KEY PERFORMANCE INDICATOR (if possible): n/a	**LICENSE:** Payment
DESCRIPTION: Amazon Machine Learning is a service that makes it easy for developers of all skill levels to use machine learning technology. Amazon Machine Learning provides visualization tools and wizards that guide you through the process of creating machine learning (ML) models without having to learn complex ML algorithms and technology. Once your models are ready, Amazon Machine Learning makes it easy to obtain predictions for your application using simple APIs, without having to implement custom prediction generation code, or manage any infrastructure. Amazon Machine Learning is based on the same proven, highly scalable, ML technology used for years by Amazon's internal data scientist community. The service uses powerful algorithms to create ML models by finding patterns in your existing data. Then, Amazon Machine Learning uses these models to process new data and generate predictions for your application. Amazon Machine Learning is highly scalable and can generate billions of predictions daily, and serve those predictions in real-time and at high throughput. With Amazon Machine Learning, there is no upfront hardware or software investment, and you pay as you go, so you can start small and scale as your application grows.	

NAME: SAP Predictive Maintenance and Service	
PRODUCER: SAP (GER)	
CATEGORY: Predictive Maintenance software	
REFERENCES: https://www.sap.com/products/predictive-maintenance.html	
KEYWORDS: software, service, predictive maintenance, cloud	**BUSINESS SECTOR AND EVALUATION:**
KEY PERFORMANCE INDICATOR (if possible): n/a	**LICENSE:** Payment after 30-day free trial
DESCRIPTION: SAP Predictive Maintenance and Service analyzes large volumes of data coming from the sensors (eg. Temperature, vibration or acceleration) and emits a warning signal even before that the machine failures. The detection of anomalies, the analysis of the spectra and machine learning techniques allow to optimize the maintenance of the asset. Sophisticated machine learning algorithms process a large amount of digital data. Furthermore, the service can be integrated into remote production systems. The user interface allows you to view data in real time. All the service is based on the SAP HANA platform.	

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NAME: RapidMiner	
PRODUCER: RapidMiner (GER)	
CATEGORY: Open-source platform for predictive maintenance	
REFERENCES: https://rapidminer.com/	
KEYWORDS: platform, open-source, predictive maintenance, machine learning	**BUSINESS SECTOR AND EVALUATION:**
KEY PERFORMANCE INDICATOR (if possible): n/a	**LICENSE:** Payment for extended versions, reduced versions for free.

DESCRIPTION: RapidMiner is a data science software platform developed by the company of the same name that provides an integrated environment for data preparation, machine learning, deep learning, text mining, and predictive analytics. It is used for business and commercial applications as well as for research, education, training, rapid prototyping, and application development and supports all steps of the machine learning process including data preparation, results visualization, model validation and optimization. According to Bloor Research, RapidMiner provides 99% of an advanced analytical solution through template-based frameworks that speed delivery and reduce errors by nearly eliminating the need to write code. RapidMiner provides data mining and machine learning procedures including: data loading and transformation (Extract, transform, load (ETL)), data preprocessing and visualization, predictive analytics and statistical modeling, evaluation, and deployment. RapidMiner is written in the Java programming language. RapidMiner provides a GUI to design and execute analytical workflows. Those workflows are called "Processes" in RapidMiner and they consist of multiple "Operators". Each operator performs a single task within the process, and the output of each operator forms the input of the next one. Alternatively, the engine can be called from other programs or used as an API. Individual functions can be called from the command line. RapidMiner provides learning schemes, models and algorithms and can be extended using R and Python scripts.
RapidMiner functionality can be extended with additional plugins which are made available via RapidMiner Marketplace. The RapidMiner Marketplace provides a platform for developers to create data analysis algorithms and publish them to the community.

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NAME: SAS	
PRODUCER: SAS Institute (USA)	
CATEGORY: Data mining and statistic suite software	
REFERENCES: https://www.sas.com/en_gb/home.html	
KEYWORDS: software, data mining, statistic analysis	**BUSINESS SECTOR AND EVALUATION:**
KEY PERFORMANCE INDICATOR (if possible): n/a	**LICENSE:** Payment

DESCRIPTION: SAS Visual Data Mining and Machine Learning supports the end-to-end data mining and machine-learning process with a comprehensive, visual (and programming) interface that handles all tasks in the analytical life cycle. It suits a variety of users and there is no application switching. From data management to model development and deployment, everyone works in the same, integrated environment.
Model development with modern machine-learning algorithms
Random forests:
Automated ensemble of decision trees to predict a single target.
Automated distribution of independent training runs.
Supports intelligent autotuning of model parameters.
Automated generation of SAS code for production scoring.
Gradient boosting:
Automated iterative search for optimal partition of the data in relation to selected label variable.
Automated resampling of input data several times with adjusted weights based on residuals.
Automated generation of weighted average for final supervised model.
Supports binary, nominal and interval labels.
Ability to customize tree training with variety of options for numbers of trees to grow, splitting criteria to apply, depth of subtrees and compute resources.
Automated stopping criteria based on validation data scoring to avoid overfitting.
Automated generation of SAS code for production scoring.
Neural networks:
Automated intelligent tuning of parameter set to identify optimal model.
Supports modeling of count data.
Intelligent defaults for most neural network parameters.
Ability to customize neural networks architecture and weights.
Ability to use an arbitrary number of hidden layers to support deep learning.
Techniques include: deep forward neural network (DNN), convolutional neural networks (CNNs), recurrent neural networks (RNNs) and autoencoders.
Supervised learning used for classification, prediction, or pattern recognition on structured and/or unstructured data.
Automatic standardization of input and target variables.
Automatic selection and use of a validation data subset.
Automatic out-of-bag validation for early stopping to avoid overfitting.
Supports intelligent autotuning of model parameters.
Automated generation of SAS code for production scoring.
Support vector machines:
Models binary target labels.
Supports linear and polynomial kernels for model training.
Ability to include continuous and categorical in/out features.
Automated scaling of input features.
Ability to apply the interior-point method and the active-set method.
Supports data partition for model validation.
Supports cross-validation for penalty selection.
Automated generation of SAS code for production scoring.
Factorization machines:
Supports the development of recommender systems based on sparse matrices of user IDs and item ratings.
Ability to apply full pairwise-interaction tensor factorization.
Includes additional categorical and numerical input features for more accurate models.
Supercharge models with timestamps, demographic data and context information.
Supports warm restart (update models with new transactions without full retraining).
Automated generation of SAS score code for production scoring.
Bayesian networks:
Learns different Bayesian network structures, including naive, tree-augmented naive (TAN), Bayesian network-augmented naive (BAN), parent-child Bayesian networks and Markov blanket.
Performs efficient variable selection through independence tests.
Selects the best model automatically from specified parameters.
Generates SAS code or an analytics store to score data.
Loads data from multiple nodes and performs computations in parallel.

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NAME: Dataiku Data Science Studio (DSS)	
PRODUCER: Oracle Corporation (USA)	
CATEGORY: Data Science platform	
REFERENCES: https://www.dataiku.com/	
KEYWORDS: platform, datascience, machine learning, deployment	**BUSINESS SECTOR AND EVALUATION:**
KEY PERFORMANCE INDICATOR (if possible): n/a	**LICENSE:** Payment

DESCRIPTION: Dataiku DSS is the collaborative data science platform that enables teams to explore, prototype, build, and deliver their own data products more efficiently. Dataiku DSS' all-in-one analytics & data science platform includes:
- Coding &/or Visual Interface: use notebooks (R, Python, Hive, Pig, Spark, etc.) or a customizable drag and drop visual interface at any step of the predictive dataflow prototyping process – from wrangling, to analysis, to modeling.
- Data Agnostic Integration: with 30+ data connectors and the ability to extend with custom plugins, connect to your existing infrastructure, automatically detect data format and schema, and push computation to your existing SQL, Hadoop, or Spark infrastructure.
- Prepare, Blend, Visualize: thanks to a visual profile of the data at every step of the analysis, interactively explore, prepare, enrich, blend, and clean data using 80+ built-in functions, from simple filters to custom Python.
- Machine Learning: leverage ML technologies (Scikit-Learn, MLlib, XGboost, etc.) in a visual UI, build & optimize models in Python or R, integrate any external ML library through code APIs (H2O, Dato, Skytree, etc.), and get instant visual & statistical feedback on model performance.
- Robust Production Deployment: bundle your whole workflow, optionally including data & models, as a single deployable and reproducible package for real-time predictions with our REST API.
- Monitoring & Version Control: make sure deployments run smoothly with dashboard monitoring & data validation policies (model metrics, drif, data consistency, etc.). If something's off, easily roll back to a previous version.

NAME: Oracle Advanced Analytics	
PRODUCER: Microsoft Corporation (USA)	
CATEGORY: Data Analytics platform	
REFERENCES: https://www.oracle.com/database/advanced-	
KEYWORDS: platform, data analysis, predictive maintenance, data mining.	**BUSINESS SECTOR AND EVALUATION:**
KEY PERFORMANCE INDICATOR (if possible): n/a	**LICENSE:** Payment

DESCRIPTION: Oracle Advanced Analytics' in-database implementation of high performance data mining and statistical algorithms extends your Oracle Database into a powerful advanced analytical platform. It allows you to solve business problems such as:
- Predicting customer behavior
- Anticipating cross/up-sell opportunities
- Improving marketing campaign response rates
- Identifying customers likely to churn
- Analyzing "market baskets" to discover associations, patterns and relationships
- Reducing fraud at every service point in the business
- Anticipating future product demand

With Oracle Advanced Analytics, you can discover patterns hidden in massive data volumes, discover new insights, make predictions and immediately transform raw data to actionable insights. Oracle Advanced Analytics is designed to deliver predictive and advanced analytics to large enterprise and operational environments.

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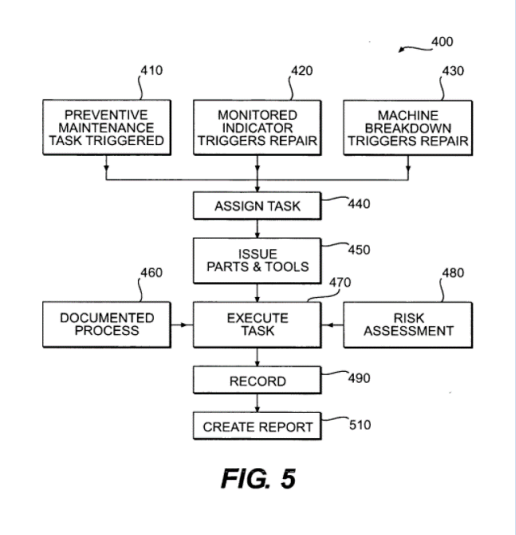
APPENDIX D - Patents Analysis

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	**DRAWING:**  FIG. 5
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	

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

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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

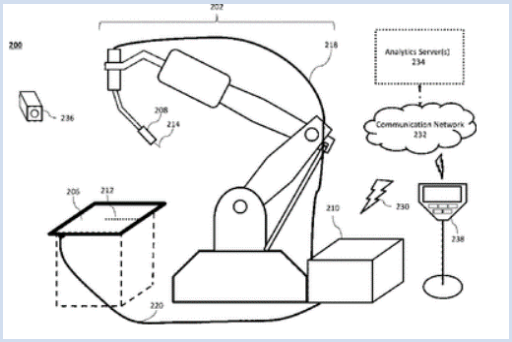
INVENTOR(S): HSU Christopher, US

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

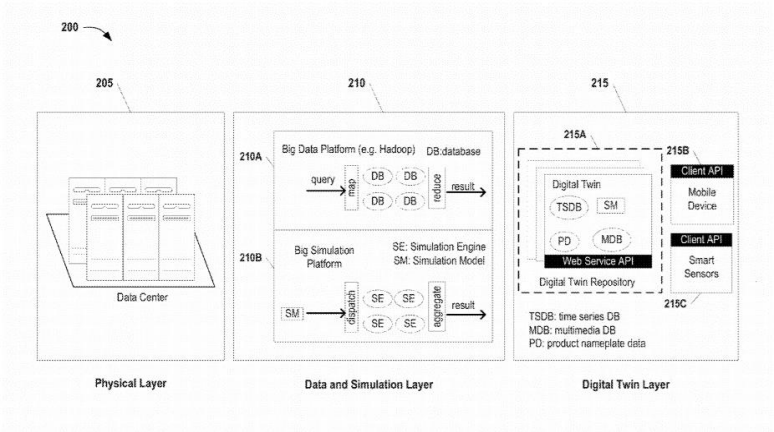
INVENTOR(S): MARTINEZ C A; SONG Z

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

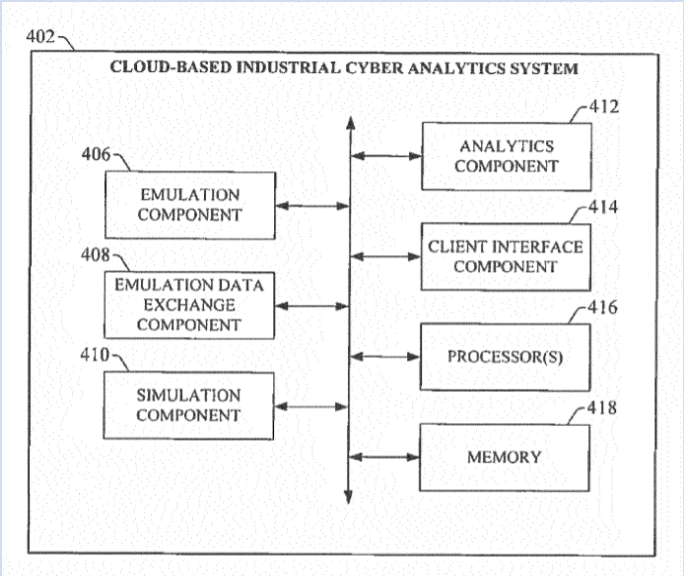
INVENTOR(S): ASENJO J L; KRIZ J; MANSOURI H; MATURANA F P

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

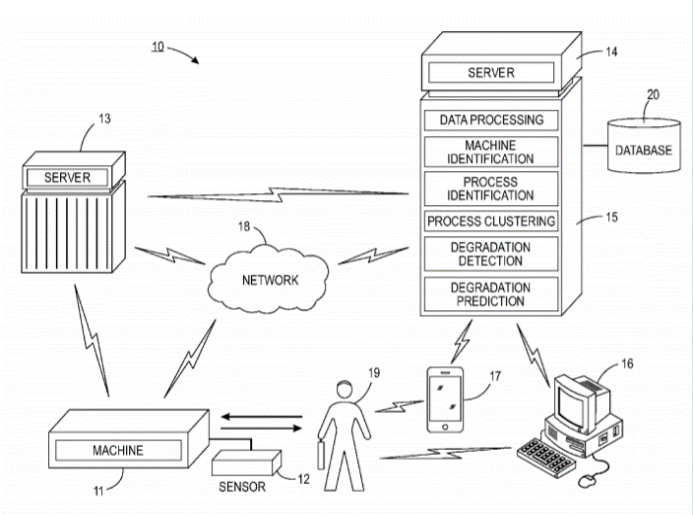
INVENTOR(S): KLEER J D; KURTOGLU T; LIAO L; MINHAS R S; RANGARAJAN A

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

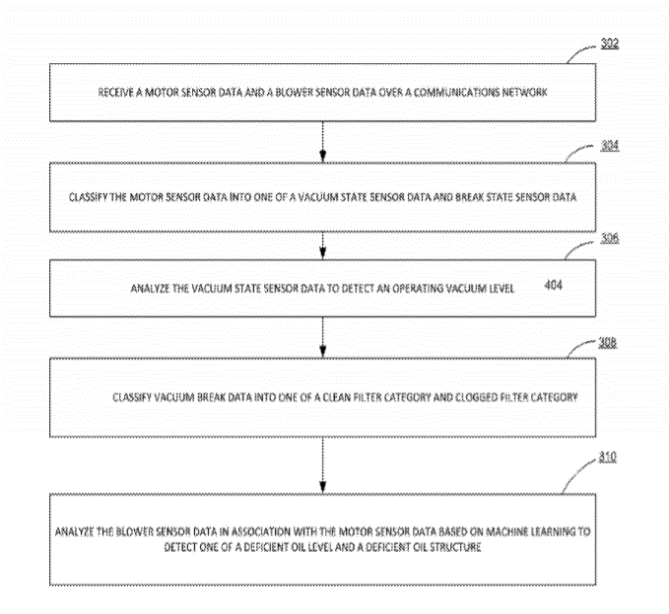
INVENTOR(S): GILLMEISTER S; PAL B; PUROHIT A

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

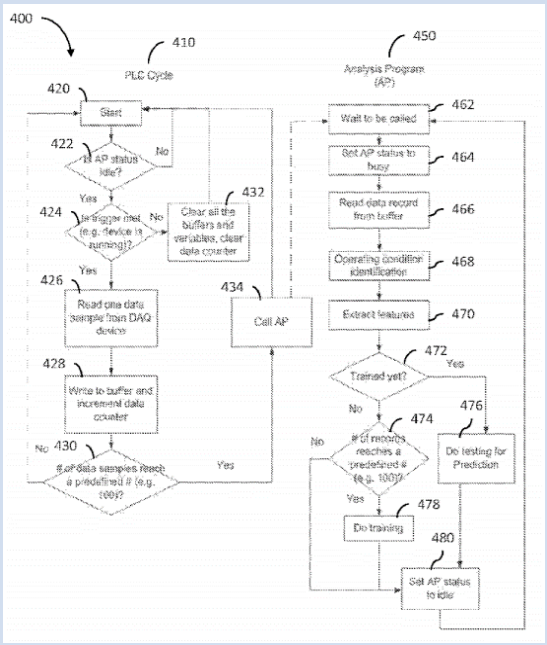
INVENTOR(S): EDMONDSON Z; ELIGUL E; LIAO L

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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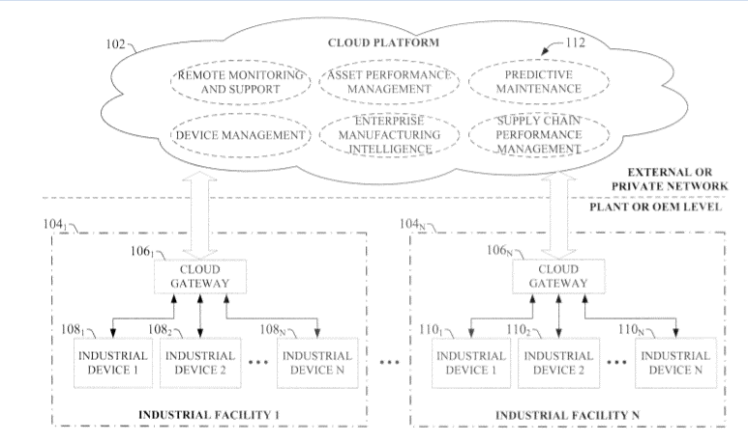
PREDICTIVE MAINTENANCE FOR INDUSTRIAL PRODUCTS USING BIG DATA - EP2801938A1	
TITLE DWPI: System for performing predictive analysis on industrial data e.g. firmware version, has predictive analysis component that predicts performance problem of industrial control system based on analysis of industrial data	**DRAWING:** 
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	

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

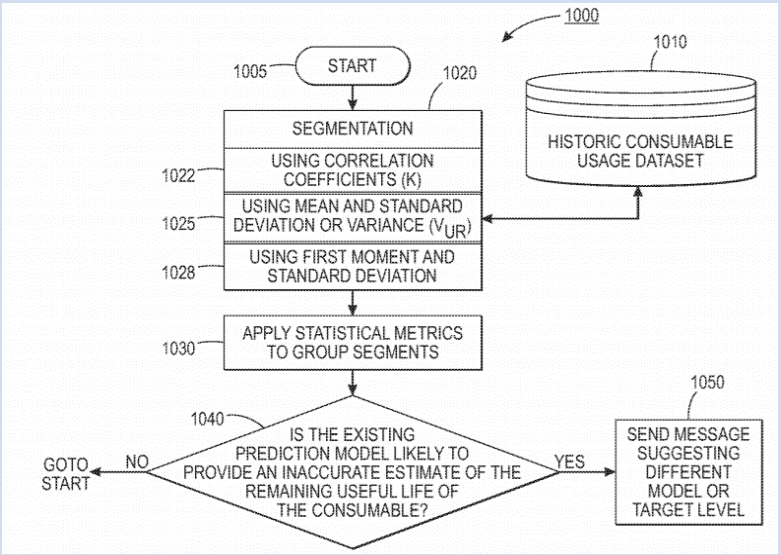
INVENTOR(S): XEROX CORP

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

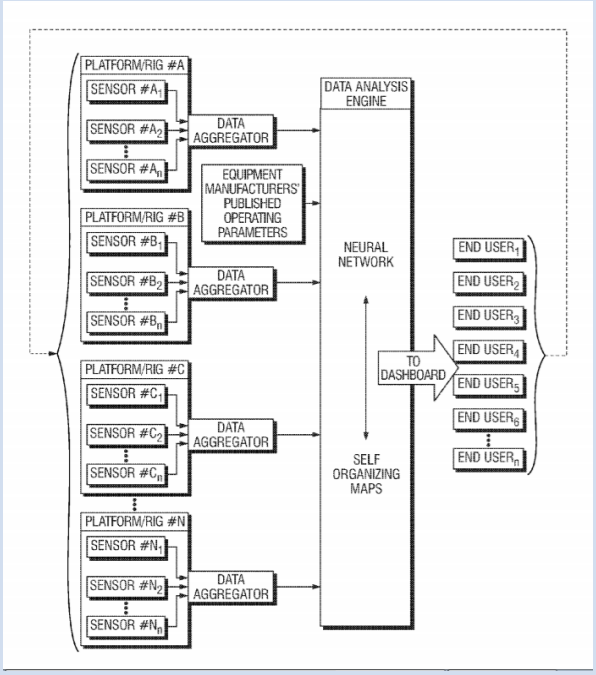
INVENTOR(S): KOZMAN J B; PIOVESAN C M

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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PART IMPROVEMENT PLAN SYSTEM OF ELEVATOR AND PART IMPROVEMENT PLAN METHOD THEREOF - JP2011020758A

TITLE DWPI: Component improvement plan system for use in elevator, has analysis processing unit to calculate replacement prediction time before failure, and management unit to notify operator about replacement time of object or component of elevator

PUBLICATION NUMBER (KIND CODE): JP2011020758A

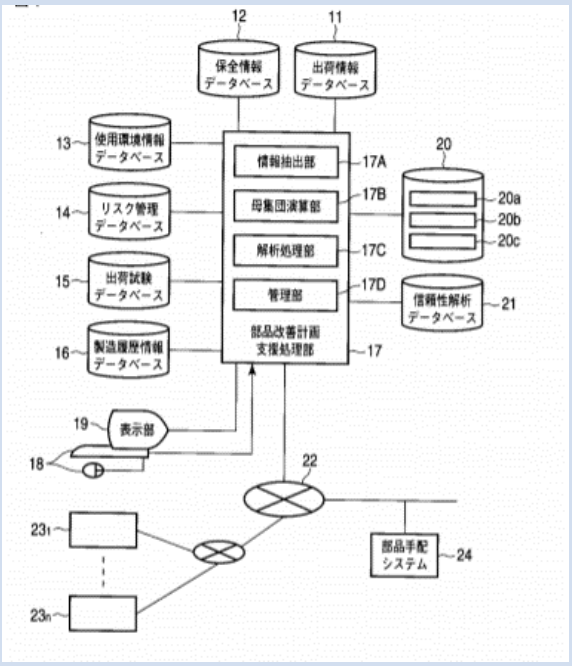
INVENTOR(S): MORIMOTO HIROYUKI

ASSIGNEE: TOSHIBA ELEVATOR KK ; TOSHIBA ELEVATOR TECHNOS KK

PUBLICATION YEAR: 2011-02-03 (A)

CURRENT IPC: B66B 5/00
B66B 3/00

DRAWING:



ABSTRACT: PROBLEM TO BE SOLVED: To present improvement content, by notifying when approaching a prediction timing, by calculating a replacement predicting timing.
SOLUTION: This part improvement plan system includes databases 11-16 for storing shipping information including part identification information on an elevator component and customer identification information of indicating a shipping destination, maintenance information including failure occurrence information, service environment information, shipping test data and manufacture history information, associated with the part identification information included in the shipping information, an information extracting part 17A for extracting the shipping information including the same shipping destination and the maintenance information including the failure occurrence, a population arithmetic operation part 17B for determining the shipping car number of an object part to the shipping destination, an analytical processing part 17C for calculating failure replacement timing of the object part by performing a Weibull analysis by generating reliability analysis information by using a plurality of reliability analyzing functions by calculating the failure car number from the shipping car number and the failure occurrence information, the analytical processing part 17C for calculating the replacement prediction timing before failure by analyzing a failure factor from the shipping test data and the manufacture history information, and a management part 17D for notifying the replacement timing of the object part.

NOVELTY: The component improvement plan system includes an analysis processing unit (17C) that implements Weibull analysis to calculate the replacement time for failure term of an object or component of an elevator. The analysis processing unit is provided to analyze a failure factor from the shipment test data and manufacture log information, and calculates the replacement prediction time before a failure. A management unit (17D) is provided to notify the operator about the replacement time of the object or component of an elevator.

USE: Component improvement plan system for use in elevator.

ADVANTAGE: Performs correct computation of elevator component replacement time before a failure occurs, and presents an elevator efficiency rate remedy from an analysis result.

DRAWING DESCRIPTION: The drawing shows the block diagram of the component improvement plan system for use on an elevator.
11-16 - Databases.
17A - Information extracting unit.
17B - Population calculating unit.
17C - Analysis processing unit.
17D - Management unit.

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METHOD AND DEVICE FOR AUTOMATING PROCEDURES FOR VERIFYING EQUIPMENT IN AN AIRCRAFT - US8761993B2

TITLE DWPI: Equipment configuration testing or evaluating method for aircraft, involves translating and executing coded command in relation with maintenance function in response to filtering of coded test command

PUBLICATION NUMBER (KIND CODE): US8761993B2

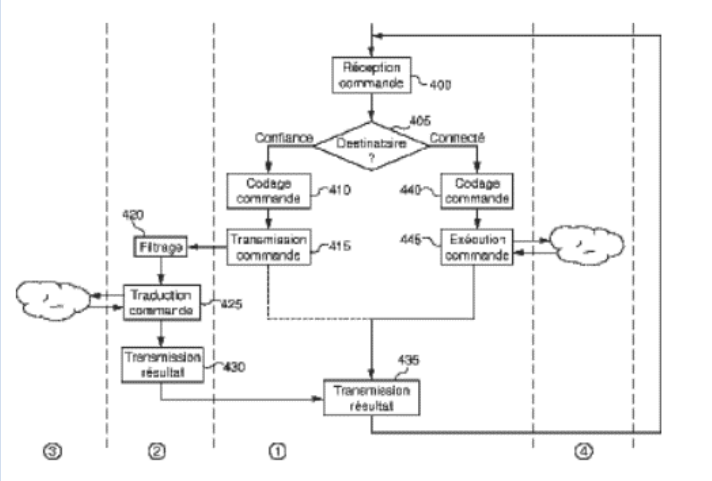
INVENTOR(S): BONZOM J; BONZOM J M; GILLET J; GILLET J P; RIC G

ASSIGNEE: AIRBUS SAS

PUBLICATION YEAR: 2014-06-24 (B2)

CURRENT IPC: G01M 17/00
G06F 7/00
G06F 11/30
G06F 19/00
G07C 5/00

DRAWING:



ABSTRACT: A method for testing or evaluating the configuration of at least one equipment item in an aircraft includes receiving at least one command to test or evaluate the configuration of the at least one equipment item via a network interface of a less secure part of an on-board information system of the aircraft. The network interface is capable of exchanging data with an information system external to the aircraft. The method also includes encoding the at least one received command and transmitting the encoded command to the secured part of the information system of the aircraft. In response to reception of the encoded command, the at least one encoded test command is filtered. In response to the filtering, the encoded command is translated and executed in relation to at least one first maintenance function of the secured part.

NOVELTY: The method involves receiving a testing or evaluating command for testing or evaluating a configuration of an equipment through a network interface i.e. Ethernet interface, and coding the received testing or evaluating command. The coded command is transmitted to a secured part of an embarked information system of an aircraft. A coded test command is filtered in response to the received coded command. The coded command is translated and executed in relation with a maintenance function in response to the filtering of the coded test command.

USE: Method for testing or evaluating a configuration of an equipment in an aircraft (claimed).

ADVANTAGE: The method permits translating and executing the coded command in relation with the maintenance function in the secured part of the information system of the aircraft from a remote station in an optimized manner without affecting the safety of the secured part of the information system, thus ensuring automatic verification of the equipment in the aircraft from the remote station during operation of the aircraft or in a final assembly line of the aircraft using the information system and its topology. The method permits frequent implementation of maintenance functions between flight phases, in order to optimize reliability of the aircraft and to increase profitability of the aircraft. The method permits maintenance applicative modules of avionics to be developed based on strict aeronautical standards i.e. DO-178B standards, for proving performance prediction level of the information system.

DRAWING DESCRIPTION: The drawing shows a flowchart illustrating an algorithm implemented in an embarked information system of an aircraft, for performing automatic tests in a final assembly line of the aircraft and/or automatic periodic verification operations executed by an airline operating the aircraft.'(Drawing includes non-English language text)'

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FEEDBACK CONTROL SYSTEM HAVING SERVOMECHANISM MONITORING SYSTEM AND METHODS OF MONITORING SERVOMECHANISMS - US9625898B2

TITLE DWPI: Feedback control system for performing industrial and assembly-type operation e.g. automotive production line, has logic controller that receives operational data and outputs real-time data corresponding to operational data

PUBLICATION NUMBER (KIND CODE): US9625898B2

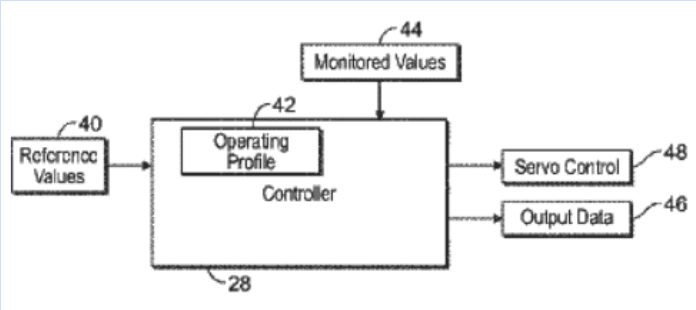
INVENTOR(S): BELTRAN H; FOLEY J

ASSIGNEE: HONDA MOTOR CO LTD

PUBLICATION YEAR: 2017-04-18 (B2)

CURRENT IPC: G05B 9/02
G05B 19/4062

DRAWING:



ABSTRACT: A feedback control system includes at least one servo unit controlling operation of a motor, wherein the at least one servo unit is configured to acquire operational data with respect to controlling the operation of the motor. The feedback control system also includes a programmable logic controller communicatively coupled to the at least one servo unit, wherein the programmable logic controller is configured to receive the operational data from the at least one servo unit and output real-time data corresponding to the operational data.

NOVELTY: The feedback control system has a servo unit that is set for controlling operation of a motor, and is configured to acquire operational data with respect to controlling the operation of the motor. A programmable logic controller is communicatively coupled to the servo unit, and is configured to receive the operational data from the servo unit and output real-time data corresponding to the operational data.

USE: Feedback control system for performing industrial and assembly-type operations e.g. automotive production lines.

ADVANTAGE: The processing speed is increased and real-time communications capabilities are provided to build cars faster and less expensively by predicting and preventing the component failures that causes costly and unplanned downtime. The monitoring system monitors the variable and/or similar operational variables accurately, continually, and in real time to allow prediction of component failure that can be preventively replaced under controlled conditions during regular maintenance rather than waiting for a catastrophic failure. The real-time operational information helps operators reduce downtime and increase productivity on the line. The individual components can be virtualized and hosted by a cloud type computational environment, so that dynamic allocation of computational power is allowed without requiring the user concerning the location, configuration, and/or specific hardware of the computer system.

DRAWING DESCRIPTION: The drawing shows a block diagram of a controller of the monitoring system.
28 - Controller.
40 - Reference values.
42 - Operating profile.
44 - Monitored values.
46 - Output data.

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TEST ASSEMBLE MANUFACTURE MOTOR VEHICLE TRAINING PLANT - DE102017006141A1

TITLE DWPI: Test assembly for manufacture of motor vehicles trained manufacturing plant.

Prüfanordnung für eine Fertigungsanlage und Verfahren zum Prüfen einer Fertigungsanlage

PUBLICATION NUMBER (KIND CODE): DE102017006141A1

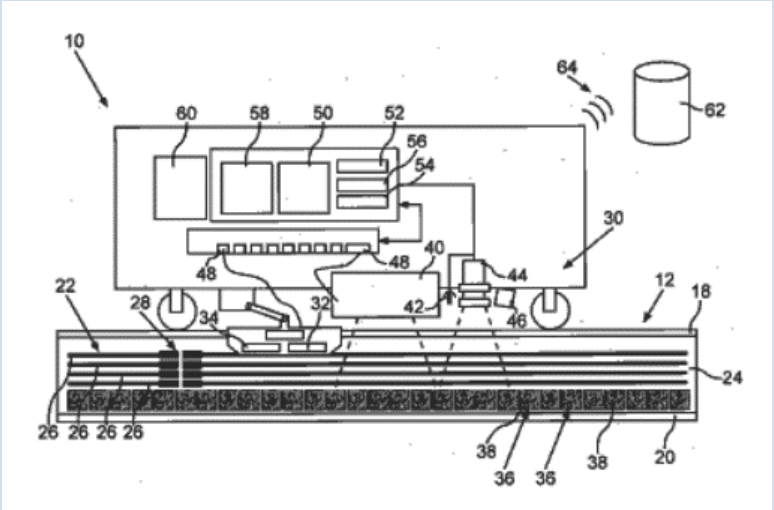
INVENTOR(S): BAUMANN J; NIEMEYER M; WOZNIAK B

ASSIGNEE: VOLKSWAGEN A.G.

PUBLICATION YEAR: 2019-01-03 (A1)

CURRENT IPC: B61L 23/04

DRAWING:



ABSTRACT: The invention relates to a test arrangement for, in particular, for manufacturing of motor vehicles formed manufacturing facility having at least one rail (12) along which a delivery device of the manufacturing equipment can be moved, and with a current rail (22) along the at least one rail (12) runs and through which the delivery device can be supplied with electrical energy. A measuring vehicle (10) is movable along the at least one rail (12). At the measuring vehicle (10) a measuring device (32, 34, 42, 44) is at least arranged for detecting data, which allow a conclusion on the state of the current rail (22). An evaluation device (50, 62) is used for evaluating the data. The invention also relates to a method for testing a production plant.

NOVELTY: The assembly has a rail (12) along which a conveying device (14) of the production plant is moved. A busbar (22) is extended along the rail and through which the conveying device is supplied with the electrical energy. A measuring vehicle (10) is movable along the rail. The measuring devices (32, 34, 42, 44) are arranged for detecting data on the measuring vehicle, which allow a conclusion about a state of the busbar and with an evaluation device (50, 62) to evaluate the data. The rail is designed as mounting rail of monorail system.

USE: Test assembly for manufacture of motor vehicles for sliding skid line trained manufacturing plant.

ADVANTAGE: The production process of the manufacturing plant is not interrupted by frequent undesirable maintenance. The maintenance takes place in good time before the malfunction of the busbar. Thus, the high productivity of the manufacturing plant is achieved. The measuring device arranged on the measuring vehicle is facilitated to acquire data which allow the conclusion to be drawn about the state of the busbar. Thus, the interruptions in the operation of the manufacturing plant are largely avoided. The condition monitoring and predictive maintenance for track-mounted conveyor techniques such as overhead monorail or push-pull lines is achieved.

DRAWING DESCRIPTION: The drawing shows a schematic view of the measuring vehicle moved along rail.
10 - Measuring vehicle.
12 - Rail.
14 - Conveying device.
22 - Busbar.
32, 34, 42, 44 - Measuring devices.
50, 62 - Evaluation devices.

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INTELLIGENT CONDITION MONITORING AND FAULT DIAGNOSTIC SYSTEM FOR PREDICTIVE MAINTENANCE - KR1322434B1

TITLE DWPI: Machine`s e.g. optical device, health condition monitoring and fault diagnosis system, has data collection function acquiring time histories of selected variables, where function sets sampling period and trigger mode for variables

PUBLICATION NUMBER (KIND CODE): KR1322434B1

INVENTOR(S): HOSEK M; KRISHNASAMY J; MARTIN H; PROCHAZKA J

ASSIGNEE: BROOKS AUTOMATION INC.

PUBLICATION YEAR: 2013-10-28 (B1)

CURRENT IPC: G06F 19/00
H01L 21/00
H01L 21/02
H01L 21/66

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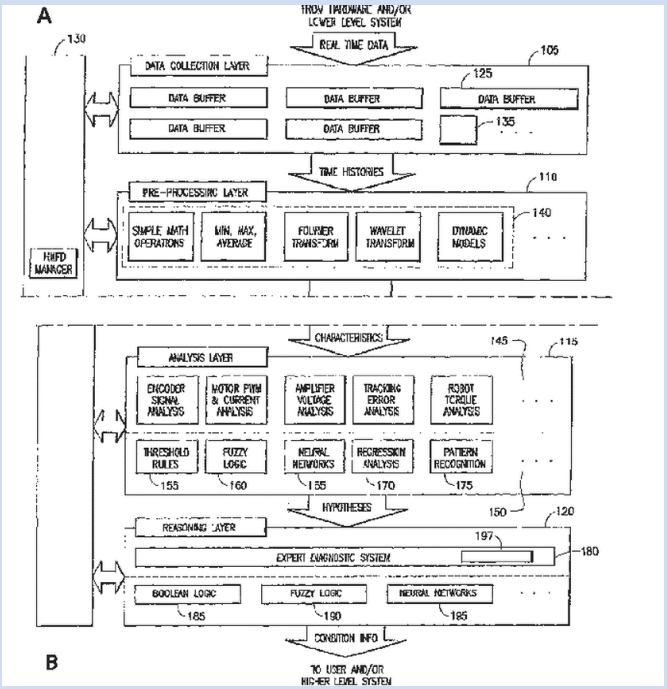

ABSTRACT: A system for condition monitoring and fault diagnosis includes a data collection function that acquires time histories of selected variables for one or more of the components, a pre-processing function that calculates specified characteristics of the time histories, an analysis function for evaluating the characteristics to produce one or more hypotheses of a condition of the one or more components, and a reasoning function for determining the condition of the one or more components from the one or more hypotheses.
The data acquisition function it is the system for the state supervising and damage detection and of obtaining the time histories of data selected about at least one elements, the preprocessing function of calculating the specific characteristics of the time histories, the evaluating analysis function property at least one assumption of the state of at least one elements is generated, and the deduction function of determining the state of at least one elements from at least one assumptions are included.

NOVELTY: The system has a data collection function (105) acquiring time histories of selected variables for components, where the data collection function sets a sampling period, trigger mode, and number of samples to be recorded for the selected variables. A pre-processing function (110) calculates specified characteristics of the time histories. An analysis function evaluates the characteristics to produce hypotheses of a condition of the components. A reasoning function determines the condition of the components from the hypotheses.

USE: Used for health condition monitoring and fault diagnosis of a machine e.g. semiconductor production system, optical, mechanical, electrical, and electromechanical devices and computer software program, that is utilized in automated manufacturing tool e.g. robotized material-handling platforms for production of a semiconductor device and also used in industrial, automotive and aerospace applications.

ADVANTAGE: The system eliminates the need for upper level controllers to configure data collection processes for different devices, each with different types of variables to monitor requiring different processing algorithms, and reduces material damage and unscheduled downtime due to unforeseen failures of robotic manipulators operating in automated manufacturing tools. The fault-diagnostic capability of the system is expected to improve the responsiveness, quality and cost of service, when a failure occurs, thus providing an improved system for monitoring conditions and diagnosing faults.

DRAWING DESCRIPTION: The drawing shows a condition monitoring and fault diagnostic system.
105 - Data collection function.
110 - Pre-processing function.
130 - Health-monitoring and fault-diagnostic (HMFD) manager.
135, 140 - Program and circuitry.

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CONVEYOR IDLER ROLLER MONITORING ASSEMBLY - WO2018141009A1

TITLE DWPI: Monitoring assembly for conveyor idler roller, has printed circuit board which has one sensor for sensing information from conveyor idler roller, a processor, and communications device for transmitting and receiving information

PUBLICATION NUMBER (KIND CODE):
WO2018141009A1

INVENTOR(S): GEDDES J M; MORGAN R

ASSIGNEE: E-MOOLA.COM PTY LTD

PUBLICATION YEAR: 2018-08-09 (A1)

CURRENT IPC: B65G 43/02
B65G 39/09
F16C 33/80
G01P 3/487
G01R 33/07

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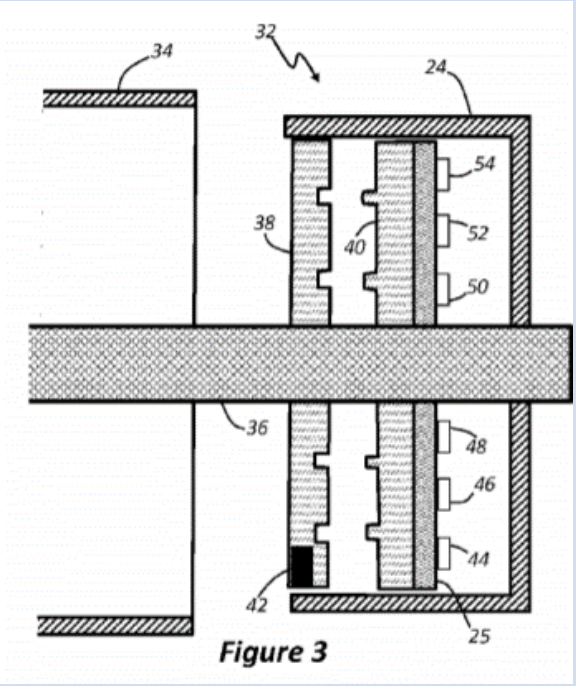

Figure 3

ABSTRACT: A monitoring assembly for monitoring assembly for monitoring a conveyor idler roller, the conveyor idler roller comprising at least one end cap, the conveyor idler roller comprising: a labyrinth seal comprising an inner seal part configured to rotate with the roller and an outer seal part configured to remain stationary within the end cap when the inner seal part is rotating; a magnet mounted on the inner seal part; and a printed circuit board mounted on the outer seal part, the printed circuit board comprising: at least one sensor for sensing information from the conveyor idler roller; a processor for recording the sensed information from the at least one sensor; and a communications device for transmitting and receiving information between the processor and an external user device.

NOVELTY: The monitoring assembly (32) has a sensor (44) for sensing information from the conveyor idler roller (34), a processor (46) for recording the sensed information from the sensor, and a communications device (48) for transmitting and receiving information between the processor and an external user device. A magnet (42) is mounted on the inner unit (38). A printed circuit board (25) is mounted on the outer unit (40). The printed circuit board has the sensor, processor, and communications device.

USE: Monitoring assembly for monitoring automatically failure of conveyor idler roller such as used in belt conveyors for handling of bulk material, e.g., coal, iron ore, phosphate, bauxite or other mineral, or transport of grain to and or from silos.

ADVANTAGE: Reduces ingress of dirt and/or water into the idler roller housing and bearing since the mechanical seal provides a tortuous path. The assembly is easily retrofitted to existing conveyor idler rollers. Saves on costly lost production to boost productivity by reducing conveyer idler roller downtime. Enables real time monitoring of a conveyer idler roller for predictive maintenance. Improves ease of use by retrofitting to an existing conveyer idler roller, and by programmability to upgrade firmware periodically. Reduces conveyer idler roller downtime, saving on costly lost production to boost productivity. Reduces the need for costly physical inspection. Ensures secure communication using authorized devices. Low energy consumption is possible, e.g. with the use of Bluetooth Low Energy (BLE) technology.

DRAWING DESCRIPTION: The drawing shows the side view of an idler roller monitoring system.
25 - Printed circuit board.
32 - Monitoring assembly.
34 - Conveyor idler roller.
38 - Inner unit.
40 - Outer unit.
42 - Magnet.
44 - Sensor.
46 - Processor.
48 - Communications device.

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A SYSTEM AND METHOD FOR CONVERTING MANUAL INDUSTRIAL MACHINES INTO AUTOMATIC INDUSTRIAL MACHINES - WO2018127940A1

TITLE DWPI: System for converting manual industrial machines into automatic industrial machines, has navigation engine provided in server, and for directing motor controller provided in add-on module to navigate industrial machine to desired location

PUBLICATION NUMBER (KIND CODE): WO2018127940A1

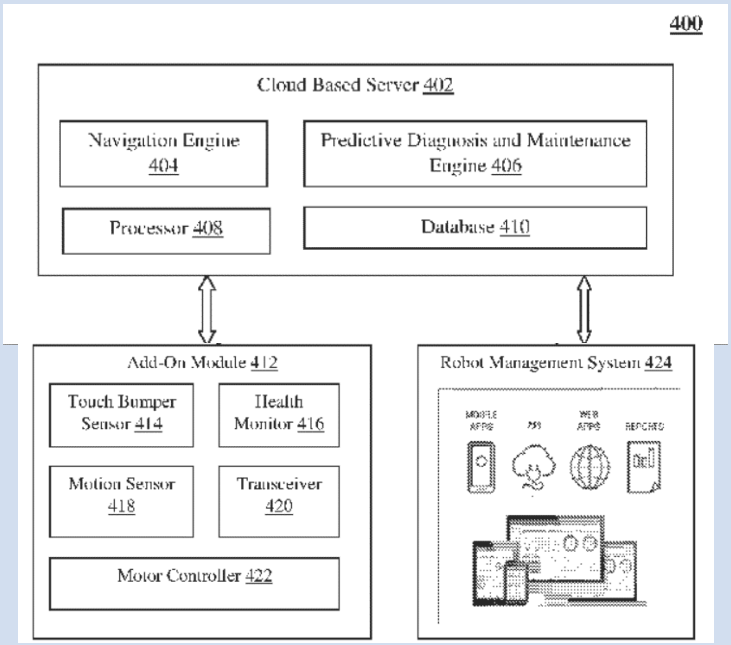
INVENTOR(S): DAS Debashis

ASSIGNEE: NOKIA CORP

PUBLICATION YEAR: 2018-07-12 (A1)

CURRENT IPC: G05B 19/418
G06Q 50/04
H04L 29/06

DRAWING:



ABSTRACT: The embodiments herein provide a system and method for converting a manual industrial machine into an automatic industrial machine through an add-on module, and providing predictive maintenance and navigation support to the automatic machines. The add-on module comprises several sensors to measure several parameters to predict impending malfunctions and breakdowns of machine components remotely through a continuous monitoring and analysis of measured parameters. A cloud based navigation engine is centrally connected to the automatic machines to take real-time decisions through data optimization and navigation algorithms.

NOVELTY: The system has a cloud based server (402) communicatively coupled with a set of automatic industrial machines. A predictive diagnosis and maintenance engine (406) is provided in the server and run on a hardware processor. The predictive diagnosis and maintenance engine predicts a set of impending malfunctions and breakdowns of multi-machine components provided in each automatic industrial machine by continuous monitoring and evaluation of measured parameters. A navigation engine (404) is provided in the server and run on the hardware processor. The navigation engine directs a motor controller (422) provided in each add-on module (412) to navigate the automated industrial machine to a desired location.

USE: System for converting manual industrial machines into automatic industrial machines and providing predictive maintenance and navigation support to automated industrial machines. Uses include but are not limited to a wet scrubber, vacuum cleaner, floor furnisher, floor polisher, sweeper, forklift, material handling machine, trolley used in hotels, restaurants, supermarkets or warehouses, rail push trolley, and a horse-drawn trolley.

ADVANTAGE: The system improves predictive maintenance and diagnostics engine availability through less machine downtime to provide maintenance strategy to avoid unforeseen failures, thus reducing associated production bottlenecks, maintenance efforts and costs, and hence improving availability of machines, performance of installed systems, possibility to monitor robots, system availability, capacity factor and service life of the automated industrial machines. The system ensures safe navigation of the automated industrial machines to avoid collision while covering an overall required area.

DRAWING DESCRIPTION: The drawing shows a block diagram of a system for automating industrial machines, and indicating a set of components provided in a cloud based server, an add-on module and a root management system.
402 - Cloud based server.
404 - Navigation engine.
406 - Predictive diagnosis and maintenance engine.
412 - Add-on module.
422 - Motor controller.

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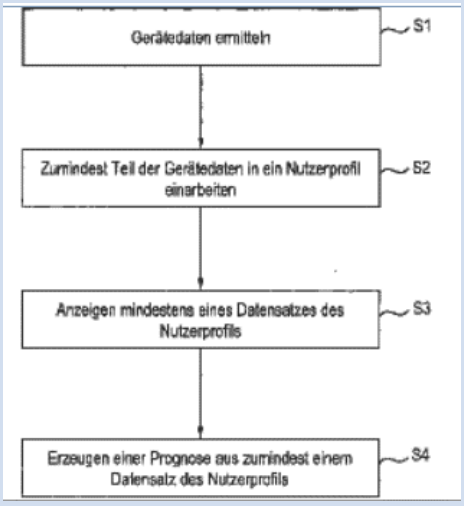
METHOD FOR PROCESSING DATA IN A DOMESTIC APPLIANCE, DOMESTIC APPLIANCE AND SYSTEM HAVING A DOMESTIC APPLICANCE AND AT LEAST ONE EXTERNAL UNIT - EP2612283A1	
TITLE DWPI: Method for processing data of household appliance i.e. washing machine, which is utilized in e.g. house, involves determining data of household appliance, and introducing part of determined data into user profile	**DRAWING:** 
PUBLICATION NUMBER (KIND CODE): EP2612283A1	
INVENTOR(S): GARBE T; HAEPP C; NEBLER C; NIEBLER C	
ASSIGNEE: BSH BOSCH SIEMENS HAUSGERAETE	
PUBLICATION YEAR: 2018-07-12 (A1)	
CURRENT IPC: D06F 35/00 G06Q 30/00 G06Q 50/00 G07C 3/08 G08C 19/00	

ABSTRACT: The method according to the invention (S1 to S4) is used for processing data in a domestic appliance (1), wherein the method has at least the following steps: appliance data from the domestic appliance (1) are ascertained (S1), at least some of the ascertained appliance data are incorporated (S2) into a user profile, and at least some of the user profile is provided (S3) for information purposes. The domestic appliance (1) according to the invention is set up to perform the steps of the method according to the invention which relate to the domestic appliance (1). In the system according to the invention comprising a domestic appliance (1) and at least one external unit (7), the domestic appliance (1) and the external unit (7) are set up to interact in order to carry out the method according to the invention.

NOVELTY: The method involves determining data of a household appliance (S1) by determining energy information, temporal information over operation of the appliance, program selection information, and program sequence information. A part of the determined data (S2) is introduced into a user profile by adding and average over actuating intervals of the appliance, joining to temporal distribution over the intervals of the appliance, and/or joining to frequency distribution over the intervals of the appliance. A dataset of the user profile is output (S3) on an external display unit of the appliance.

USE: Method for processing data of a household appliance (claimed) i.e. washing machine, which is utilized in a house and a condominium. Can also be used for a dryer, a refrigerator, a cooking device, a coffee machine and a microwave oven.

ADVANTAGE: The data of the household appliance is determined, and the part of the determined data is introduced into the user profile with high accuracy, thus providing a versatile and user-friendly utilization of the household appliance. The method provides the user profile to a customer service team for effective repair and/or maintenance, and effectively reduces energy consumption of the appliance.

DRAWING DESCRIPTION: The drawing shows a flow chart illustrating a method for processing data of a household appliance.'(Drawing includes non-English language text)'
S1 - Step for determining data of household appliance.
S2 - Step for introducing part of determined data.
S3 - Step for outputting dataset of user profile.
S4 - Step for producing prediction from dataset of user profile.

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A HOUSEHOLD APPLIANCE FAILURE RISK PREDICTION SYSTEM AND METHOD - CN103592919B	
TITLE DWPI: Household electrical appliance device fault risk estimating system, has domestic environment detect system unit receiving household environment information uploaded with device fault risks for transmitting device fault information to user	**DRAWING:**
PUBLICATION NUMBER (KIND CODE): CN103592919B	
INVENTOR(S): CUI J; TIAN H; WANG A; WANG B; YU Z; ZHAO H	
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PUBLICATION YEAR: 2016-03-09 (B)	
CURRENT IPC: G05B 19/418	

ABSTRACT: The invention relates to a household appliance failure risk prediction system and fault diagnosis system method and appliance server uploaded by the household appliance itself information and home environment detecting system detecting the household environment information with the preset failure risk prediction model, judging whether the household appliance fault risk exists, if there is a risk of failure, the failure risk of the household device information and the failure reason to the user and after-sale service. In one aspect, the user can discover the appliance device has failure risk and process in time, so as to reduce the maintenance cost and time, meanwhile, it can reduce risk of failure this time period energy consumption. On the other hand, after-sale service can find problem and can timely provide after-sale service to the user, so as to improve the satisfaction degree of the user.

NOVELTY: The system has a risk estimating system unit connected with a household appliance device. Household environment information is transmitted to an upper appliance fault pre-diagnosis system server and a household appliance fault pre-diagnosis system server. The household environment information is uploaded with device fault risks in a domestic environment detect system unit for transmitting electrical device fault information to a user. The household appliance device is connected to the domestic environment detect system unit through a home server. The system unit is fixed to a database server.

USE: The system improves user satisfaction degree.

ADVANTAGE: The data of the household appliance is determined, and the part of the determined data is introduced into the user profile with high accuracy, thus providing a versatile and user-friendly utilization of the household appliance. The method provides the user profile to a customer service team for effective repair and/or maintenance, and effectively reduces energy consumption of the appliance.

DRAWING DESCRIPTION: n/a

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PREDICTIVE ROLLING BEARING MAINTENANCE - IN201106345P4

TITLE DWPI: Rolling bearing fault predicting method for servo motor, involves space-sampling processed vibration signal based on processed position signal, and predicting fault in rolling bearing based on space-sampled vibration signal

PUBLICATION NUMBER (KIND CODE):
IN201106345P4

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PUBLICATION YEAR: 2012-11-09 (A1)

CURRENT IPC: G01M 13/04
G06F 19/00
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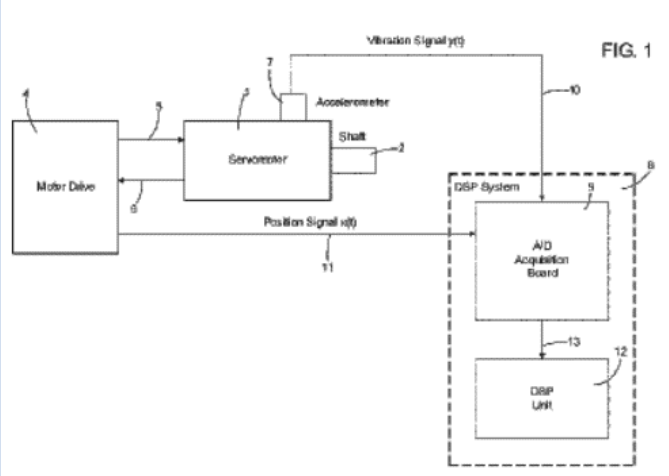
G01M 13/02

DRAWING:



ABSTRACT: A method of predicting a fault in a rolling bearing, the rolling bearing including inner and outer rings and rolling bodies evenly angularly distributed therebetween, the method comprising:. processing (in the DSP system 8) a position signal (x(t)) indicative of a relative angular position of the inner ring with respect to the outer rings, and a vibration signal (y(t)) (by the accelerometer 7) indicative of speed-related vibrations in the rolling bearing, such that they correspond to either an angular displacement of the rolling bodies equal to an integer number of angular gaps between adjacent rolling bodies or an integer number of complete rotations of the inner ring with respect to the outer ring;. space sampling (in the A/D acquisition board 9) the processed vibration signal (y(t)) based on the processed position signal (x(t)); and. predicting a fault in the rolling bearing based on the space-sampled vibration signal (y(t)).

NOVELTY: The method involves processing position signal (x-t) indicative of relative angular position of an inner ring with respect to an outer ring. Vibration signal (y-t) indicative of speed-related vibration in a rolling bearing is processed. Angular displacement of the rolling bodies is computed with respect to the inner and outer rings. The processed vibration signal is space-sampled based on the processed position signal. Fault in the rolling bearing is predicted based on the space-sampled vibration signal.

USE: Method for predicting fault in a rolling bearing of a servo motor of a filling machine/packaging line distribution equipment that is utilized in a food packaging plant.

ADVANTAGE: The method enables the fault in the rolling bearing to be accurately predicted, so that rolling bearing is properly repaired, thus reducing operating and maintenance cost of the filling machine/packaging line distribution equipment.

DRAWING DESCRIPTION: The drawing shows a block representation of a data acquisition system for performing a modified computed order tracking process.
x-t - Position signal.
y-t - Vibration signal.
1 - Servo motor.
2 - Shaft.
4 - Motor drive.

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