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(54) Title: METHOD AND SYSTEM FOR OPTIMIZING PERFORMANCE OF A PHYSICAL MACHINE

(57) Abstract: A method for optimizing performance of a physical machine is disclosed. The method includes monitoring sensor data in near real-time from each of a plurality of sensors. The sensor data is associated with one or more attributes associated with the physical machine which includes a plurality of components. The plurality of sensors is integrated on the physical machine. The method further includes correlating the sensor data with a simulation model of the physical machine to dynamically predict one or more parameters associated with at least one component of the physical machine, iteratively reconfiguring at least one of the plurality of components of the physical machine based on the one or more predicted parameters, for obtaining a optimum operation of the physical machine, and displaying the one or more predicted parameters associated with the at least one component from the plurality of components of the physical machine.

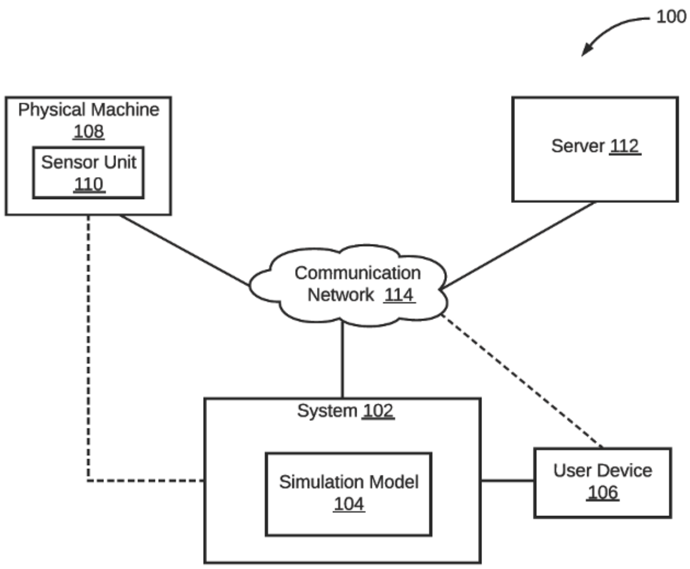

FIG. 1

<u>FORM 2</u>

THE PATENTS ACT 1970
(39 OF 1970)
&
The Patent Rules, 2003

Complete Specification

(See Section 10 and Rule 13)

1. TITLE OF THE INVENTION

METHOD AND SYSTEM FOR OPTIMIZING PERFORMANCE OF A PHYSICAL MACHINE

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3. PREAMBLE TO THE DESCRIPTION

COMPLETE

The following specification describes the invention and the manner in which it is to be performed

DESCRIPTION

Technical Field

[001] This disclosure relates generally to simulation, and more particularly relates to implementing a system and a method for monitoring and optimizing performance of a physical machine by simulation.

BACKGROUND

[002] Generally, conventional mechanisms for monitoring and controlling of physical machines (such as, an electric vehicle) are costly, time consuming, and inaccurate. In many cases, such conventional mechanisms may require precautions to be taken for specific diagnosis for ensuring optimum performance. For example, conventional mechanisms for monitoring and controlling of physical machines may require human intervention with manual validation steps.

[003] Typically, electric vehicles may have multiple subsystems (such as, electro-mechanical systems). Such subsystems are a combination of critical components and non-components, such as, a power source (like, lithium ion or sodium ion battery). Conventional technologies focus on improvement of the power source to maximize efficient working range of components of various subsystems of physical machines (such as, the electric vehicle).

[004] Accordingly, there is a need for method and system to accurately and automatically monitor and continually assess the health of the components, and predict fatigue lives of systems that employ them.

SUMMARY

[005] In accordance with an embodiment, a method of optimizing performance of a physical machine is disclosed. The method includes monitoring sensor data in near real-time from each of a plurality of sensors. The sensor data is associated with one or more attributes associated with the physical machine which includes a plurality of components. The plurality of sensors is integrated on the physical machine. The method further includes correlating the sensor data with a simulation model of the physical machine to dynamically predict one or more parameters associated with at least one component of the physical machine, iteratively reconfiguring at least one of the plurality of components of the physical machine based on the one or more predicted parameters, for obtaining an optimum operation of the physical machine, and displaying the one or more predicted parameters associated with the at least one component from the plurality of components of the physical machine.

[006] In accordance with an embodiment, a system for optimizing performance of a physical machine is disclosed. The system includes a processor and a memory communicatively coupled to the processor. The memory is configured to store a simulation model, and processor-executable instructions, wherein the processor-executable instructions, on execution, cause the processor to: monitor sensor data in near real-time from each of a plurality of sensors, wherein the sensor data is associated with one or more attributes associated with the physical machine, wherein the physical machine comprises a plurality of components, and wherein the plurality of sensors is integrated on the physical machine; correlate the sensor data with a simulation model of the physical machine to dynamically predict one or more parameters associated with at least one component from the plurality of components of the physical machine; iteratively reconfigure at least one of the plurality of components of the physical machine based on the one or more predicted parameters, for obtaining an optimum operation of the physical machine; and display the one or more predicted parameters associated with the at least one component from the plurality of components of the physical machine.

[007] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[008] The accompanying drawings, which are incorporated in and constitute a part of this disclosure, illustrate exemplary embodiments and, together with the description, serve to explain the disclosed principles.

[009] FIG. 1 is a block diagram that illustrates an environment for a system for optimizing performance of a physical machine, in accordance with an embodiment of the disclosure.

[010] FIG. 2 is a functional block diagram that illustrates an exemplary system for optimizing performance of a physical machine, in accordance with an embodiment of the disclosure.

[011] FIG. 3 is a diagram that illustrates exemplary operations for optimizing performance of a physical machine, in accordance with an embodiment of the disclosure.

[012] FIG. 4 is a block diagram that illustrates a simulation model employed for an automotive gearbox of an electric vehicle for optimizing performance of the electric vehicle, in accordance with an embodiment of the disclosure.

[013] FIG. 5A is a block diagram that illustrates generation of simulation model using different modes for calculating natural frequency, in accordance with an embodiment of the disclosure.

[014] FIG. 5B-5C collectively illustrate parameters involved in modeling of a physical machine using a simulation model for optimizing performance of the physical machine, in accordance with an embodiment of the disclosure.

[015] FIG. 6 is a flowchart that illustrates an exemplary method for optimizing performance of the physical machine, in accordance with an embodiment of the disclosure.

DETAILED DESCRIPTION

[016] Exemplary embodiments are described with reference to the accompanying drawings. Wherever convenient, the same reference numbers are used throughout the drawings to refer to the same or like parts. While examples and features of disclosed principles are described herein, modifications, adaptations, and other implementations are possible without departing from the spirit and scope of the disclosed embodiments. It is intended that the following detailed description be considered as exemplary only, with the true scope and spirit being indicated by the following claims. Additional illustrative embodiments are listed below.

[017] The following described implementations may be found in the disclosed method and system for optimizing performance of a physical machine. Exemplary aspects of the disclosure provide a system that trains a simulation model to be suitable for real-time inference, while maintaining a balance between a prediction accuracy for a set of input parameters associated with diagnosing deviation in performance of a physical machine and fatigue life of various components of the physical machine. The disclosed system makes use of Internet of Things (IoT) for connecting with the physical machine.

[018] Exemplary aspects of the disclosure provide the system of a physical machine to provide valuable data even when a sub-system (such as, a gearbox) of the physical machine (such as, an electric vehicle) fails prematurely. Such data may be used for testing a digital model (also referred as simulation model) with variations in, without limitations, material properties, dimensional variations, vibrational data, and temperature of oil coolant. The disclosed system may also detect anomalies in a test setup using the digital model. The anomalies can lead to a failure of a testing machine (such as, the physical machine), thereby incurring cost. Therefore, the disclosed system may save cost by detecting anomalies before failure of the physical machine.

[019] Exemplary aspects of the disclosure provide the system of a physical machine to improve quality of sub systems of the physical machine and facilitate enhanced insight into performance of sub systems of the physical machine in various real-time (or near real time) applications and environments. In accordance with an embodiment, users can remotely monitor configurations with customized products using the system. Further, the disclosed system may help in increased reliability of equipment and production lines, improved Overall Equipment Effectiveness (OEE) through reduced downtime and improved performance, improved productivity, reduced risk in various areas, such as, product availability, marketplace reputation. lower maintenance costs by predicting maintenance issues before breakdowns occur, faster production times, efficient supply and delivery chains and improved profits.

[020] FIG. 1 is a block diagram that illustrates an environment for a system for optimizing performance of a physical machine, in accordance with an embodiment of the disclosure. With reference to FIG.1, there is shown an environment 100. The environment 100 includes a system 102, a simulation model 104, a user device 106, a physical machine 108, sensor unit 110, a server 112 and a communication network 114. The system 102 may be communicatively coupled to the sensor unit 110 and the user device 106, via the communication network 114. The system 102 may include the simulation model 104, for example, as part of an application stored in memory of the system 102.

[021] The system 102 may include suitable logic, circuitry, interfaces, and/or code that may be configured to use a simulation model 104 for optimizing performance of a twinned physical machine, such as, the physical machine 108. The system 102 may include the simulation model 104 for interaction and matching configuration with the physical machine 108. The system 102 may be configured to train the simulation model 104 for optimizing performance of the physical machine 108. In accordance with an embodiment, the simulation model 104 may be trained on the sensor data from the sensor unit 110 for synchronized functioning of each of the plurality of components of the physical machine 108 using a regression function.

[022] In accordance with an embodiment, the sensor data from the sensor unit 110 comprises at least one of temperature data, vibrational data, dimensional variations data, and material properties variations data. Additionally, the simulation model 104, once trained, may be deployable for applications (such as, a digital twin application) which may take actions or generate real-time or near real-time inferences. By way of example, the system 102 may be implemented as a plurality of distributed cloud-based resources by use of several technologies that are well known to those skilled in the art. Other examples of implementation of the system 102 may include, but are not limited to, machine/equipment diagnostic equipment, a web/cloud server, an application server, a media server, and a Consumer Electronic (CE) device.

[023] The system 102 may correspond to a digital representation of the physical machine 108, a digital replica of physical machine 108 in the physical world. The system 102 may use real world data (sensor data 110) to create simulations that can predict how the physical machine 108 will perform. The system 102 may be integrated with internet of things (IoT) and to enhance performance of the physical machine 108 using the simulation model 104.

[024] In accordance with an embodiment, the system 102 may be configured to receive the sensor data from the sensor unit 110 of the physical machine 108 to monitor and control sub systems or components of the physical machine 108. The sensor data may be received from a plurality of sensors integrated on the physical machine 108. In accordance with an embodiment, the plurality of sensors may include, without limitation, an accelerometer, a speed sensor, a thermocouple, and a vibration sensor. In accordance with an embodiment, the system 102 may be configured to compute fatigue life of one or more components of the physical machine 108. In accordance with an embodiment, the system 102 may be run at a single location or distributed on several locations or over the physical system 108 for enhanced proximity the sensor unit 110.

[025] In accordance with an embodiment, the simulation model 104 of the system 102 may be configured to be tuned to a set of parameters that describe working state of the physical machine 108 in real time. For example, the simulation model 104 may comprise a physics system model with adaptive learning to fine tune physics equations of a gearbox model, or a regression-fit model and/or a simplified physics-based table-based model. The difference between predictions and the received sensor data from the sensor unit 110, may be used to tune input model parameters such that the system 102 matches the physical machine 108.

[026] The simulation model 104 may include electronic data, such as, for example, a software program, code of the software program, libraries, applications, scripts, or other logic/instructions for execution by a processing device, such as the system 102 and the user device 106. Additionally, or alternatively, the simulation model 104 may be implemented using hardware, such as a processor, a microprocessor (e.g., to perform or control performance of one or more operations), a field-programmable gate array (FPGA), or an application-specific integrated circuit (ASIC). In some embodiments, the simulation model 104 may be implemented using a combination of both the hardware and the software program.

[027] The user device 106 may include suitable logic, circuitry, interfaces, and/or code that may be configured to render alert messages and notifications, based on performance degradation of components of the physical machine 108. The functionalities of the user device 106 may be implemented in portable devices, such as a high-speed computing device, and/or non-portable devices, such as a server. Examples of the user device 106 may include, but are not limited to, a smart phone, a mobile device, or a laptop.

[028] Although in FIG. 1, the system 102, the user device 106, and the server 112 are shown as separate entities, this disclosure is not so limited. Accordingly, in some embodiments, the entire functionality of the server 112 and the user device 106 may be included in the system 102, without a deviation from scope of the disclosure.

[029] In accordance with an embodiment, the system 102 may store information into and/or retrieve information from the server 112. The server 112 may be locally stored or reside remote from the system 102. Although a single digital twin of the physical machine 108 is shown in FIG. 1, any number of such devices may be included. Moreover, various devices described herein might be combined according to embodiments of the present disclosure. In accordance with an embodiment, the server 112 may be configured to store data associated with operation of the system 102 for analysis of the physical machine 108.

[030] The communication network 114 may include a communication medium through which the system 102, the physical machine 108, the server 112, and the user device 106 may communicate with each other. Examples of the communication network 114 may include, but are not limited to, the Internet, a cloud network, a Wireless Fidelity (Wi-Fi) network, a Personal Area Network (PAN), a Local Area Network (LAN), or a Metropolitan Area Network (MAN). Various devices in the environment 100 may be configured to connect to the communication network 114, in accordance with various wired and wireless communication protocols. Examples of such wired and wireless communication protocols may include, but are not limited to, a Transmission Control Protocol and Internet Protocol (TCP/IP), User Datagram Protocol (UDP), Hypertext Transfer Protocol (HTTP), File Transfer Protocol (FTP), Zig Bee, EDGE, IEEE 802.11, light fidelity(Li-Fi), 802.16, IEEE 802.11s, IEEE 802.11g, multi-hop communication, wireless access point (AP), device to device communication, cellular communication protocols, and Bluetooth (BT) communication protocols.

[031] In operation, a process may be initialized to train the simulation model 104 on the sensor data from the sensor unit 110 for synchronized functioning of each component of the physical machine 108 using a regression function. In training of the simulation model 104, one or more of the set of parameters may be updated. By way of example, the simulation model 104 may be trained to understand a complex behavior from the sensor data for optimizing performance of the physical machine 108.

[032] In accordance with an embodiment, the system 102 may be configured to monitor sensor data in near real time from each of the plurality of sensors. In accordance with an embodiment, a set of input parameter values and a set of output parameter values of the physical machine may be assessed from the sensor data of the sensor unit 108. In accordance with an embodiment, the system 102 may be configured to determine performance degradation of at least one component from the plurality of components of the physical machine using the simulation model. In accordance with an embodiment, at least one of the set of output parameter values below a predefined threshold value may be indicative of the performance degradation of the at least one component. In accordance with an embodiment, the system 102 may be configured to control operation of each of the plurality of components of the physical machine 108 for synchronized functioning of each of the plurality of components of the physical machine 108, based on the determined performance degradation. In accordance with an embodiment, at least one of the set of input parameter values may be changed to maintain each of the set of output parameters at reference values. In accordance with an embodiment, the physical machine 108 may be in operating state.

[033] In accordance with an embodiment, the system 102 may be configured to control a display device of the user device 106 to render notification for alert based on the performance degradation of the at least one component from the plurality of components of the physical machine 108 that helps in maintenance scheduling and optimal control of the physical machine 108.

[034] FIG. 2 is a functional block diagram that illustrates an exemplary disease system for optimizing performance of a physical machine, in accordance with an embodiment of the disclosure. FIG. 2 is explained in conjunction with elements from FIG. 1.

[035] With reference to FIG. 2, there is shown a block diagram 200 of the system 102. The system 102 may include a processor 202, a memory 204, an input/output (I/O) device 206, a network interface 208, an application interface 210, and a persistent data storage 212. The system 102 may also include the simulation model 104, as part of, for example, a software application for decisioning in performance of the physical machine 108. The processor 202 may be communicatively coupled to the memory 204, the I/O device 206, the network interface 208, the application interface 210, and the persistent data storage 212. In one or more embodiments, the system 102 may also include a provision/functionality to receive sensor data via the sensor unit 110.

[036] The processor 202 may include suitable logic, circuitry, interfaces, and/or code that may be configured to train the simulation model 104 for controlling operation of each of the plurality of components of the physical machine for synchronized functioning of each of the plurality of components of the physical machine. Once trained, the simulation model 104 may be either deployed on other electronic devices (e.g., the user device 106) or on the system

102 for real time prediction of the sensor data from the sensor unit 110 of the physical machine 108. The processor 202 may be implemented based on a number of processor technologies, which may be known to one ordinarily skilled in the art. Examples of implementations of the processor 202 may be a Graphics Processing Unit (GPU), a Reduced Instruction Set Computing (RISC) processor, an Application-Specific Integrated Circuit (ASIC) processor, a Complex Instruction Set Computing (CISC) processor, a microcontroller, Artificial Intelligence (AI) accelerator chips, a co-processor, a central processing unit (CPU), and/or a combination thereof.

[037] The memory 204 may include suitable logic, circuitry, and/or interfaces that may be configured to store instructions executable by the processor 202. Additionally, the memory 204 may be configured to store sensor data from the sensor unit 110, program code of the simulation model 104 and/or the software application that may incorporate the program code of the simulation model 104. Examples of implementation of the memory 204 may include, but are not limited to, Random Access Memory (RAM), Read Only Memory (ROM), Electrically Erasable Programmable Read-Only Memory (EEPROM), Hard Disk Drive (HDD), a Solid-State Drive (SSD), a CPU cache, and/or a Secure Digital (SD) card.

[038] The I/O device 206 may include suitable logic, circuitry, and/or interfaces that may be configured to act as an I/O interface between a user and the system 102. The user may include an operator or site engineer who operates the system 102. The I/O device 206 may include various input and output devices, which may be configured to communicate with different operational components of the system 102. Examples of the I/O device 206 may include, but are not limited to, a touch screen, a keyboard, a mouse, a joystick, a microphone, and a display screen.

[039] The network interface 208 may include suitable logic, circuitry, interfaces, and/or code that may be configured to facilitate different components of the system 102 to communicate with other devices, such as the user device 106, in the environment 100, via the communication network 114. The network interface 208 may be configured to implement known technologies to support wired or wireless communication. Components of the network interface 208 may include, but are not limited to an antenna, a radio frequency (RF) transceiver, one or more amplifiers, a tuner, one or more oscillators, a digital signal processor, a coder-decoder (CODEC) chipset, an identity module, and/or a local buffer.

[040] The network interface 208 may be configured to communicate via offline and online wireless communication with networks, such as the Internet, an Intranet, and/or a wireless network, such as a cellular telephone network, a wireless local area network (WLAN), personal area network, and/or a metropolitan area network (MAN). The wireless communication may use any of a plurality of communication standards, protocols and technologies, such as Global System for Mobile Communications (GSM), Enhanced Data GSM Environment (EDGE), wideband code division multiple access (W-CDMA), code division multiple access (CDMA), LTE, time division multiple access (TDMA), Bluetooth, Wireless Fidelity (Wi-Fi) (such as IEEE 802.11, IEEE 802.11b, IEEE 802.11g, IEEE 802.11n, and/or any other IEEE 802.11 protocol), voice over Internet Protocol (VoIP), Wi-MAX, Internet-of-Things (IoT) technology, Machine-Type-Communication (MTC) technology, a protocol for email, instant messaging, and/or Short Message Service (SMS).

[041] The application interface 210 may be configured as a medium for the user to interact with the system 102. The application interface 210 may be configured to have a dynamic interface that may change in accordance with preferences set by the user and configuration of the system 102. In some embodiments, the application interface 210 may correspond to a user interface of one or more applications installed on the system 102.

[042] The persistent data storage 212 may include suitable logic, circuitry, and/or interfaces that may be configured to store program instructions executable by the processor 202, operating systems, and/or application-specific information, such as logs and application-specific databases. The persistent data storage 212 may include a computer-readable storage media for carrying or having computer-executable instructions or data structures stored thereon. Such computer-readable storage media may include any available media that may be accessed by a general-purpose or special-purpose computer, such as the processor 202.

[043] By way of example, and not limitation, such computer-readable storage media may include tangible or non-transitory computer-readable storage media including, but not limited to, Compact Disc Read-Only Memory (CD-ROM) or other optical disk storage, magnetic disk storage or other magnetic storage devices (e.g., Hard-Disk Drive (HDD)), flash memory devices (e.g., Solid State Drive (SSD), Secure Digital (SD) card, other solid state memory devices), or any other storage medium which may be used to carry or store particular program code in the form of computer-executable instructions or data structures and which may be accessed by a general-purpose or special-purpose computer. Combinations of the above may also be included within the scope of computer-readable storage media.

[044] Computer-executable instructions may include, for example, instructions and data configured to cause the processor 202 to perform a certain operation or a set of operations associated with the system 102. The functions or operations executed by the system 102, as described in FIG. 1, may be performed by the processor 202. In accordance with an embodiment, additionally, or alternatively, the operations of the processor 202 are performed by various modules of the physical machine 108.

[045] FIG. 3 is a schematic diagram 300 that illustrates exemplary operations for testing simulation model of system for optimizing performance of a gear box of a physical machine, in accordance with an embodiment of the disclosure. FIG. 3 is explained in conjunction with elements from FIG. 1 and FIG. 2.

[046] In accordance with an embodiment, the system 102 may be configured to receive sensor data for the sensor unit 110. Automotive gear box may be driven by a motor fitted with a vibration sensor, a temperature sensor and an RPM (Rotation per Minute) sensor.

[047] In accordance with an embodiment, the sensor data may include vibration sensor for gearbox for vibration monitoring, temperature sensor to measure oil temperature of the gear box, speed sensor at gear box location for output measurement. In accordance with an embodiment, the sensor data may be collected by a data logger and analyzed by the system 102. In accordance with an embodiment, the sensor data may be stored in the server 112 or a data logger (not shown in the figure). In accordance with an embodiment, the system 102 may use a simulation model, such as, a Finite element analysis (FEA) model for data mining and preparation for FEA correlations and predictions. In accordance with an embodiment, simulation FEA Model with ANSYS-ROM (Reduced Order Modeling) may be used by the system 102. In accordance with an embodiment, the simulation model 104 may have ANSYS 3D FEA model of the gear box to simulate for optimizing performance of electric vehicle associated with the gear box. In accordance with an embodiment, output parameter values are used for calculating fatigue life of gear teeth and to plot Campbell diagram in real time or near real time.

[048] In accordance with an embodiment, physical hardware and simulation FEA data results may be twined in a display unit of the user device 106 by showing input torque, vibration versus time graph, and temperature of lubrications. In accordance with an embodiment, the simulation model 104 may use a regression equation which can connect the functioning of all the components of the physical machine 108 and help synchronized functioning of all the components of the physical machine 108. When one of components of the physical machine 108 operate below an expected efficiency, then parameters of remaining components may be automatically enhanced to maintain a required output. This is achieved with the simulation model 104 by using a regression study using DOE and a response surface may be created. The response surface may continuously alter the operating range of components to make the entire physical machine to perform to a required potential.

[049] FIG. 4 is a block diagram that illustrates a simulation model employed for an automotive gearbox of an electric vehicle for optimizing performance of the electric vehicle, in accordance with an embodiment of the disclosure. FIG. 4 is explained in conjunction with elements from FIG. 1, FIG. 2, and FIG. 3.

[050] A reverse loop system level digital twin (referred as system 102) may be in progress to monitor all gear box parameters and study the interactions. For example, a set of input parameter values and a set of output parameter values of an electric vehicle associated with the gear box are assessed from the sensor data of the sensor unit.

[051] In accordance with an embodiment, the system 102 may be configured to determine performance degradation of at least one component of the electric vehicle using the simulation model (such as, digital model ANSYS ROM). In accordance with an embodiment, at least one of the set of output parameter values below a predefined threshold value may be indicative of the performance degradation of the at least one component, such as the gear box.

[052] In accordance with an embodiment, the system 102 may be configured to control operation of each component of the electric vehicle for synchronized functioning of each of the plurality of components of the electric vehicle, based on the determined performance degradation. In accordance with an embodiment, at least one of the set of input parameter values may be changed to maintain each of the set of output parameters at reference values. In accordance with an embodiment, the physical machine may be in operating state.

[053] FIG. 5A is a block diagram that illustrates generation of simulation model using different modes for calculating natural frequency, in accordance with an embodiment of the disclosure. FIG. 5A is explained in conjunction with elements from FIG. 1 to FIG. 4.

[054] With reference to FIG. 5A, the simulation model is generated for calculating natural frequency using various modes of frequency.

[055] FIG. 5B-5C collectively illustrate parameters involved in modeling of a physical machine using a simulation model for optimizing performance of the physical machine, in accordance with an embodiment of the disclosure. FIG. 5 is explained in conjunction with elements from FIG. 1 to FIG. 5A.

[056] The tabular representation in FIG. 5B illustrates speed (or rotational velocity) of load associated with gear box of an electric vehicle, FEA acceleration predicted by the simulation model 104 and measured acceleration from the sensor unit 110. Acceleration may be indicative of the condition of the gear box. With reference to FIG. 5C, dynamic Campbell diagram plots the gear box vibration against natural frequency of the gear box. This can be remotely monitored and changes in the rotation per minute (RPM) can be made to avoid resonance until a scheduled maintenance is planned.

[057] In accordance with an embodiment, load is given as Rotational Velocity values 2000 rad/s to crank shaft of the gear box. FEA model matches 91.4 % of Physical model. The simulation model 104 (rigid dynamic model) may be validated for 1440 RMP. The dynamic Campbell diagram help to monitor performance when the systems start from 500 RPM to 1440 RPM and provide feedback to shift the operating RPM in case of resonance.

[058] FIG. 6 is a flowchart that illustrates an exemplary method for optimizing performance of the physical machine, in accordance with an embodiment of the disclosure. With reference to FIG. 6, there is shown a flowchart 600. The operations of the exemplary method may be executed by any computing system, for example, by the system 102 of FIG. 1. The operations of the flowchart 600 may start at 602 and proceed to 604.

[059] At step 602, sensor data may be monitored in near real-time from each of a plurality of sensors. The sensor data is associated with one or more attributes associated with the physical machine. The physical machine includes a plurality of components. The plurality of sensors is integrated on the physical machine. In accordance with an embodiment, the plurality of sensors includes at least one of an accelerometer, a speed sensor, a thermocouple, and a vibration sensor. In accordance with an embodiment, a set of input parameter values and a set of output parameter values of a physical machine may be assessed from the sensor data.

[060] At step 604, the sensor data may be correlated with a simulation model of the physical machine to dynamically predict one or more parameters associated with at least one component from the plurality of components of the physical machine. At step 606, at least one of the plurality of components of the physical machine may be iteratively reconfigured based on the one or more predicted parameters, for obtaining a optimum operation of the physical machine. At step 608, the one or more predicted parameters associated with the at least one component from the plurality of components of the physical machine may be displayed to a user.

[061] The one or more predicted parameters may include anticipated failure and remaining life of the one or more the plurality of components of the physical machine. The method may further include determining performance degradation of at least one component from the plurality of components of the physical machine based on the correlation. At least one of the set of output parameter values below a predefined threshold value is indicative of the performance degradation of the at least one component. The method may further include iteratively reconfiguring at least one of the plurality of components of the physical machine based on the performance degradation of the at least one component. In accordance with an embodiment, at least one of the set of output parameter values below a predefined threshold value may be indicative of the performance degradation of the at least one component.

[062] In accordance with an embodiment, the simulation model includes a “Finite Element analysis (FEA)”, model of the physical machine. The simulation model may be trained on the sensor data for synchronized functioning of each of the plurality of components of the physical machine using a regression function. In accordance with an embodiment, the sensor data comprises at least one of temperature data, vibrational data, dimensional variations data, and material properties variations data.

[063] In accordance with an embodiment, the simulation model may be further trained on a three-dimensional model of the at least one component from the plurality of components of the physical machine. In accordance with an embodiment, the system 102 may be configured to compute fatigue life of the at least one component of the physical machine, based on the at least one of the set of output parameter values. In accordance with an embodiment, the system 102 may be configured to determine Campbell performance of the at least one component of the physical machine in near real time, wherein a dynamic Campbell plot is generated for the at least one component of the physical machine using the sensor data for determining the Campbell performance. In accordance with an embodiment, the system 102 may be configured to identify an anomaly in the physical machine during simulation using the simulation model to avoid failure and shut down of the physical machine. In accordance with an embodiment, at least one of the set of input parameter values is changed to maintain each of the set of output parameters at reference values, and wherein the physical machine is in operating state. In accordance with an embodiment, the system 102 may be configured to control a display device to render notification for alert based on the performance degradation of the at least one component from the plurality of components of the physical machine.

[064] Furthermore, one or more computer-readable storage media may be utilized in implementing embodiments consistent with the present disclosure. A computer-readable storage medium refers to any type of physical memory on which information or data readable by a processor may be stored. Thus, a computer-readable storage medium may store instructions for execution by one or more processors, including instructions for causing the processor(s) to perform steps or stages consistent with the embodiments described herein. The term "computer-readable medium" should be understood to include tangible items and exclude carrier waves and transient signals, i.e., be non-transitory. Examples include random access memory (RAM), read-only memory (ROM), volatile memory, nonvolatile memory, hard drives, CD ROMs, DVDs, flash drives, disks, and any other known physical storage media.

[065] It will be appreciated that, for clarity purposes, the above description has described embodiments of the disclosure with reference to different functional units and processors. However, it will be apparent that any suitable distribution of functionality between different functional units, processors or domains may be used without detracting from the disclosure. For example, functionality illustrated to be performed by separate processors or controllers may be performed by the same processor or controller. Hence, references to specific functional units are only to be seen as references to suitable means for providing the described functionality, rather than indicative of a strict logical or physical structure or organization.

[066] Although the present disclosure has been described in connection with some embodiments, it is not intended to be limited to the specific form set forth herein. Rather, the scope of the present disclosure is limited only by the claims. Additionally, although a feature may appear to be described in connection with particular embodiments, one skilled in the art would recognize that various features of the described embodiments may be combined in accordance with the disclosure.

[067] Furthermore, although individually listed, a plurality of means, elements or process steps may be implemented by, for example, a single unit or processor. Additionally, although individual features may be included in different claims, these may possibly be advantageously combined, and the inclusion in different claims does not imply that a combination of features is not feasible and/or advantageous. Also, the inclusion of a feature in one category of claims does not imply a limitation to this category, but rather the feature may be equally applicable to other claim categories, as appropriate.

WE CLAIM:

1. A method of optimizing performance of a physical machine, the method comprising:

monitoring sensor data in near real-time from each of a plurality of sensors, wherein the sensor data is associated with one or more attributes associated with the physical machine, wherein the physical machine comprises a plurality of components, and wherein the plurality of sensors is integrated on the physical machine;

correlating the sensor data with a simulation model of the physical machine to dynamically predict one or more parameters associated with at least one component from the plurality of components of the physical machine;

iteratively reconfiguring at least one of the plurality of components of the physical machine based on the one or more predicted parameters, for obtaining a optimum operation of the physical machine; and

displaying the one or more predicted parameters associated with the at least one component from the plurality of components of the physical machine.

2. The method as claimed in claim 1, wherein the one or more predicted parameters comprise anticipated failure and remaining life of the one or more the plurality of components of the physical machine.

3. The method as claimed in claim 1, further comprising:

determining performance degradation of at least one component from the plurality of components of the physical machine based on the correlation, wherein at least one of the set of output parameter values below a predefined threshold value is indicative of the performance degradation of the at least one component;

iteratively reconfiguring at least one of the plurality of components of the physical machine based on the performance degradation of the at least one component.

4. The method as claimed in claim 1, wherein the simulation model comprises a “Finite Element analysis (FEA)” model of the physical machine, and wherein the simulation model is trained on the sensor data for synchronized functioning of each of the plurality of components of the physical machine using a regression function, wherein the sensor data comprises at least one of temperature data, vibrational data, dimensional variations data, and material properties variations data.

5. The method as claimed in claim 4, wherein the simulation model is further trained on a three-dimensional model of the at least one component from the plurality of components of the physical machine.

6. The method as claimed in claim 1, further comprising controlling a display device to render notification for alert based on the performance degradation of the at least one component from the plurality of components of the physical machine.

7. The method as claimed in claim 1, further comprising determining Campbell performance of the at least one component of the physical machine in near real time, wherein a dynamic Campbell plot is generated for the at least one component of the physical machine using the sensor data for determining the Campbell performance.

8. The method as claimed in claim 1, wherein the plurality of sensors comprises at least one of an accelerometer, a speed sensor, a thermocouple, and a vibration sensor.

9. A system for optimizing performance of a physical machine, the system comprising:

a processor; and

a memory communicatively coupled to the processor, wherein the memory is configured to store a simulation model, and processor-executable instructions, wherein the processor-executable instructions, on execution, cause the processor to:

monitor sensor data in near real-time from each of a plurality of sensors, wherein the sensor data is associated with one or more attributes associated with the physical machine, wherein the physical machine comprises a plurality of components, and wherein the plurality of sensors is integrated on the physical machine;

correlate the sensor data with a simulation model of the physical machine to dynamically predict one or more parameters associated with at least one component from the plurality of components of the physical machine;

iteratively reconfigure at least one of the plurality of components of the physical machine based on the one or more predicted parameters, for obtaining an optimum operation of the physical machine; and

display the one or more predicted parameters associated with the at least one component from the plurality of components of the physical machine.

Dated this 08th day of June 2022

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ABSTRACT

METHOD AND SYSTEM FOR OPTIMIZING PERFORMANCE OF A PHYSICAL MACHINE

A method for optimizing performance of a physical machine is disclosed. The method includes monitoring sensor data in near real-time from each of a plurality of sensors. The sensor data is associated with one or more attributes associated with the physical machine which includes a plurality of components. The plurality of sensors is integrated on the physical machine. The method further includes correlating the sensor data with a simulation model of the physical machine to dynamically predict one or more parameters associated with at least one component of the physical machine, iteratively reconfiguring at least one of the plurality of components of the physical machine based on the one or more predicted parameters, for obtaining a optimum operation of the physical machine, and displaying the one or more predicted parameters associated with the at least one component from the plurality of components of the physical machine.

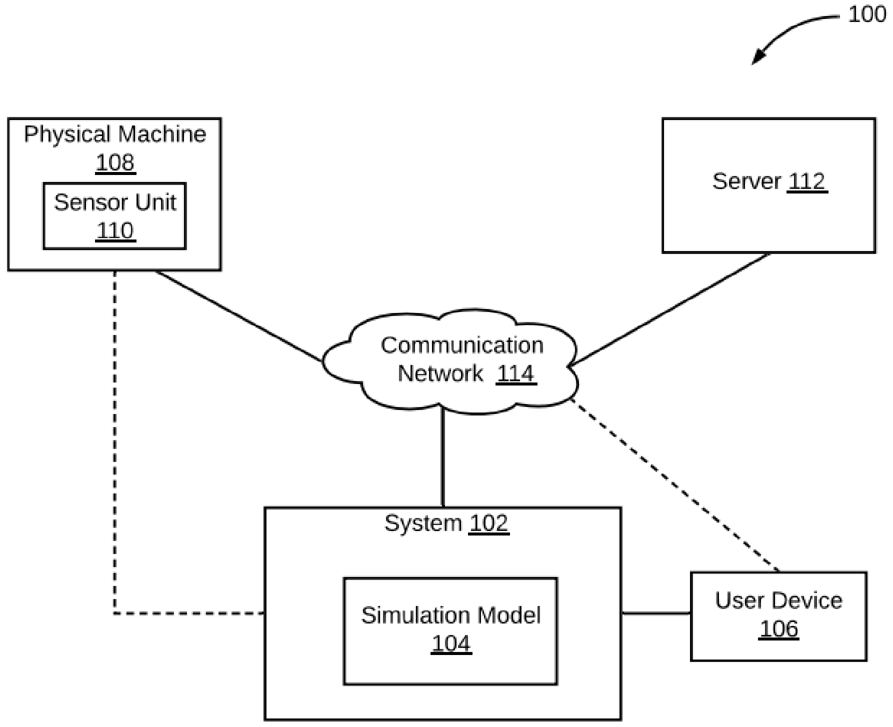

Fig. 1

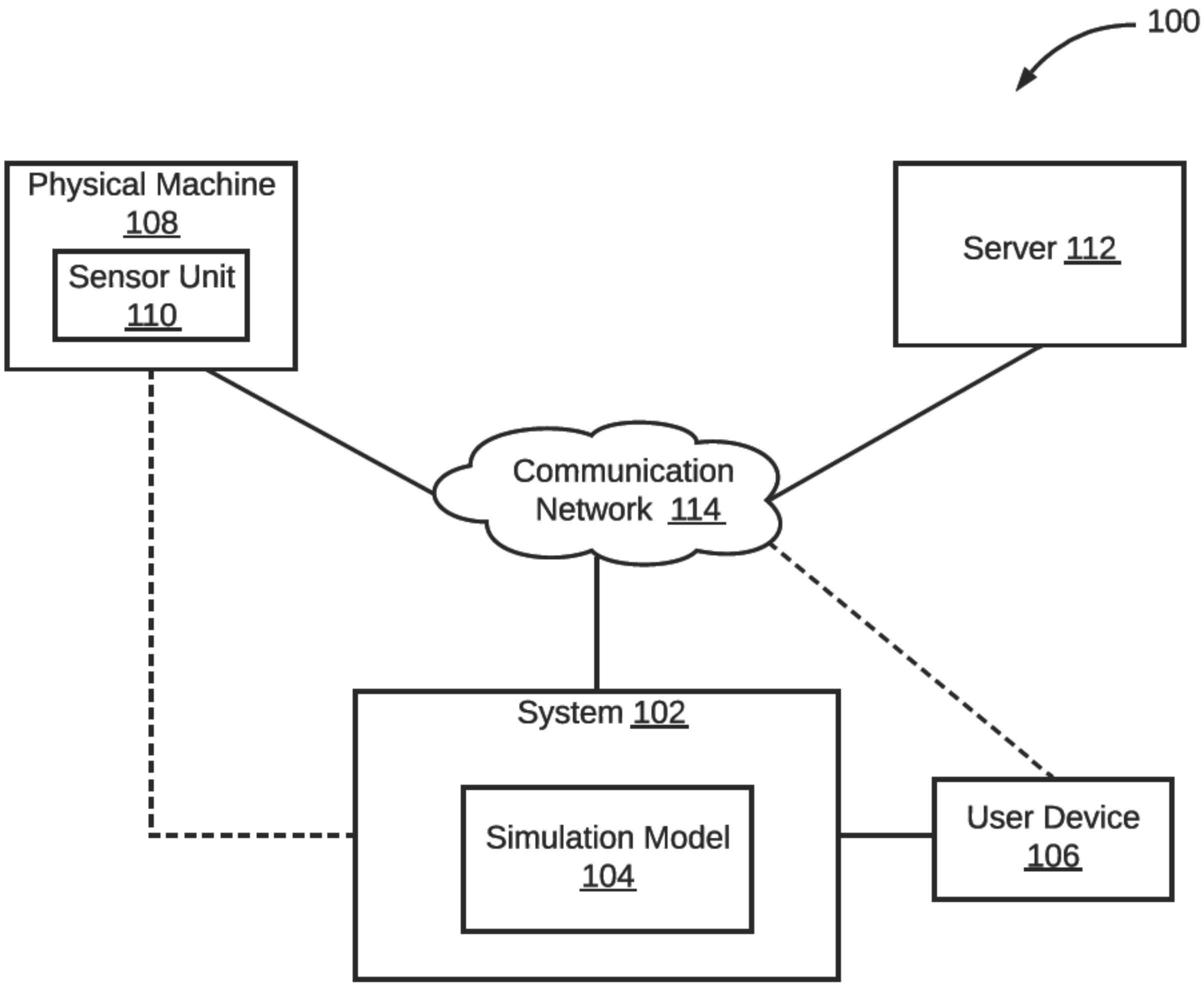

FIG. 1

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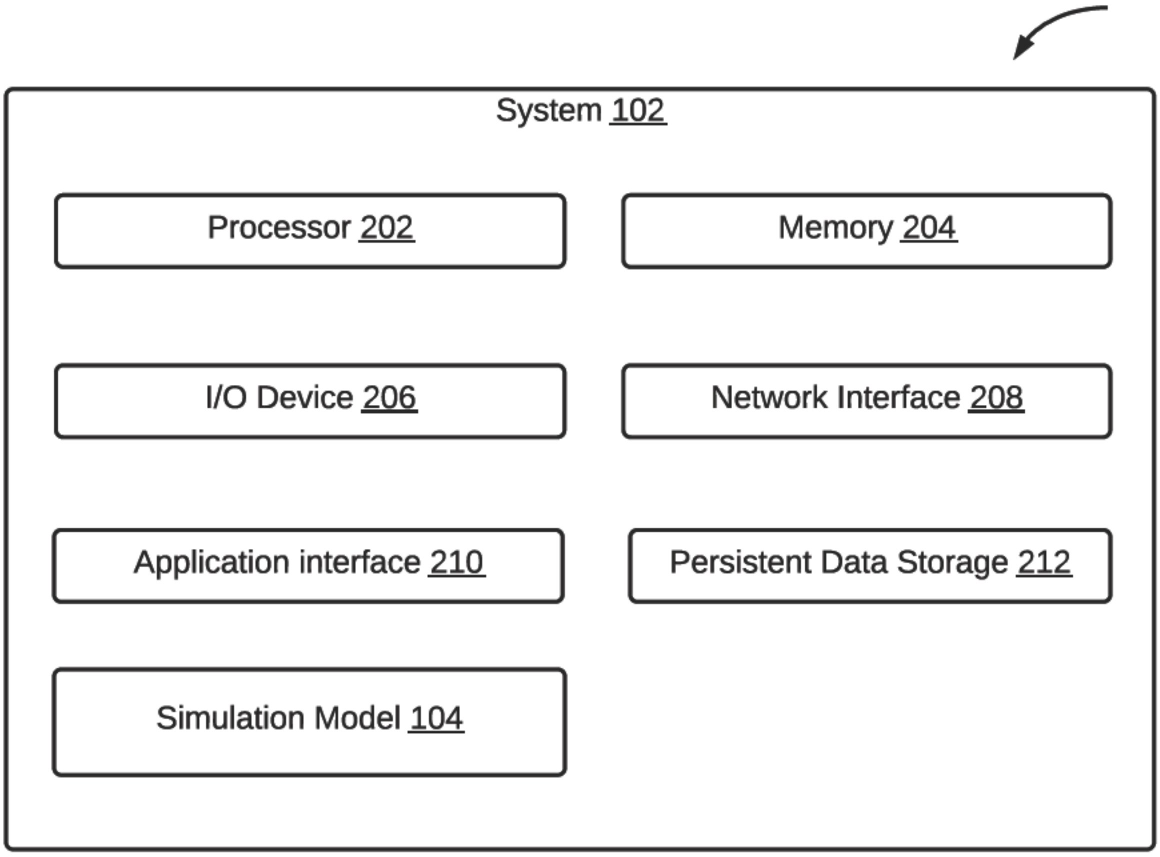

FIG. 2

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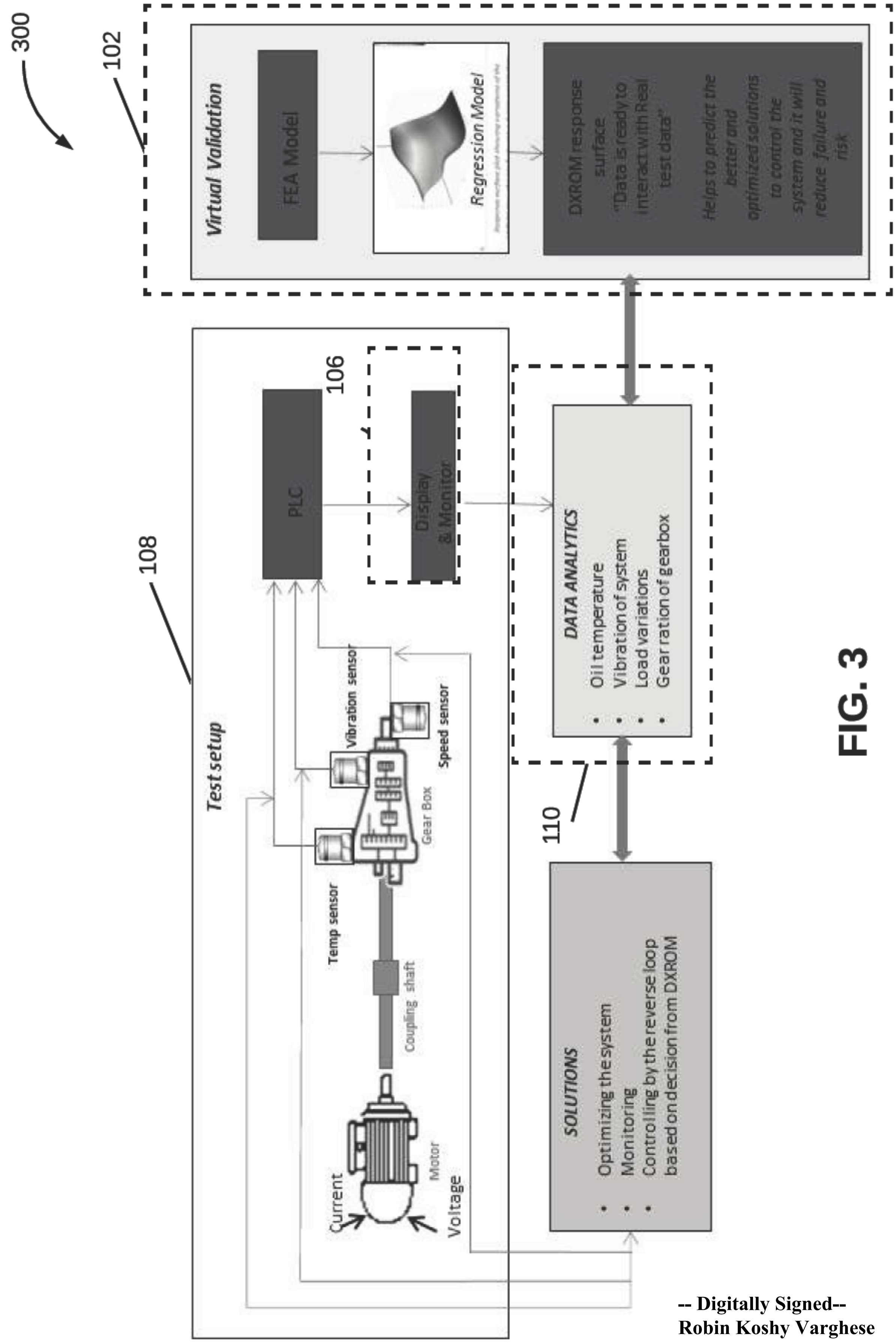

FIG. 3

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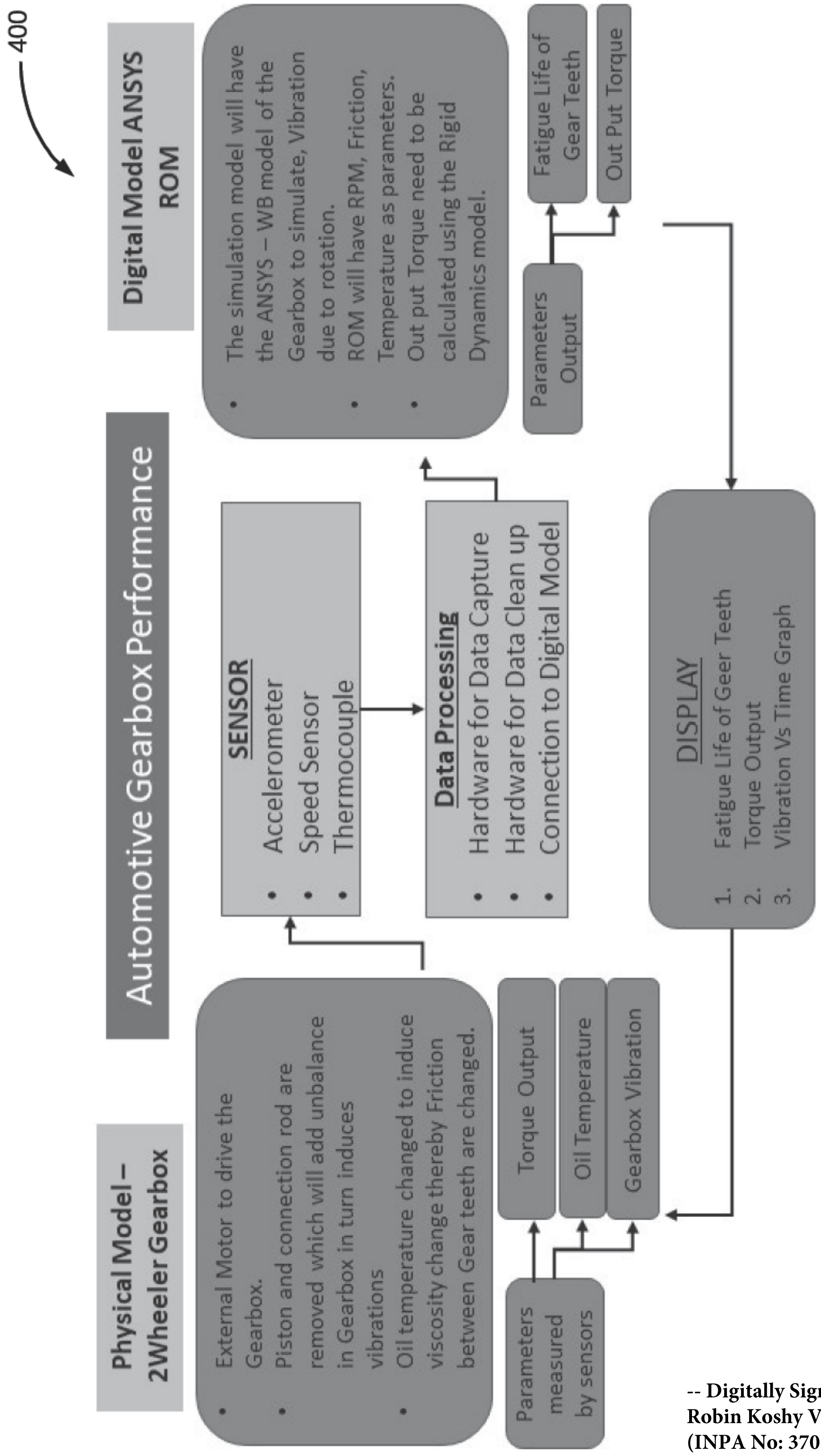

FIG. 4

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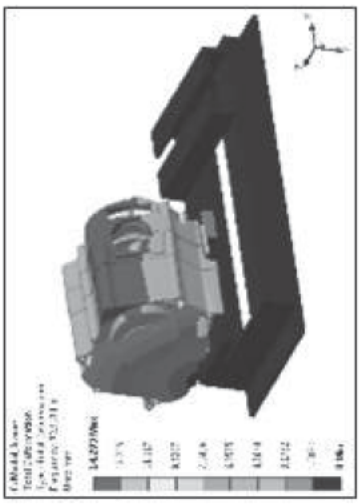
500A



Mode 1 , 72.617 Hz

Mode 3 , 446.61 Hz

Mode 1, Animation, Please put on Slide show mode

Mode	Frequency
1	72.617
2	243.52
3	446.61
4	585.83

Mode 2 , 243.52 Hz

FIG. 5A

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500B

S.No.	Speed	FEA	Measured
1	500	1787.60	1780.2
2	600	-403.70	-400.5
3	700	1567.8	1562.7
4	800	-2915.90	-2911.9
5	900	4863.40	4860.0
6	1000	694.65	691.6
7	1100	13337.00	12231.0
8	1200	-168.39	-168.39
9	1300	1074.00	1074.0
10	1400	913.48	910.5
11	1440	694.91	635.24

FIG. 5B

500C

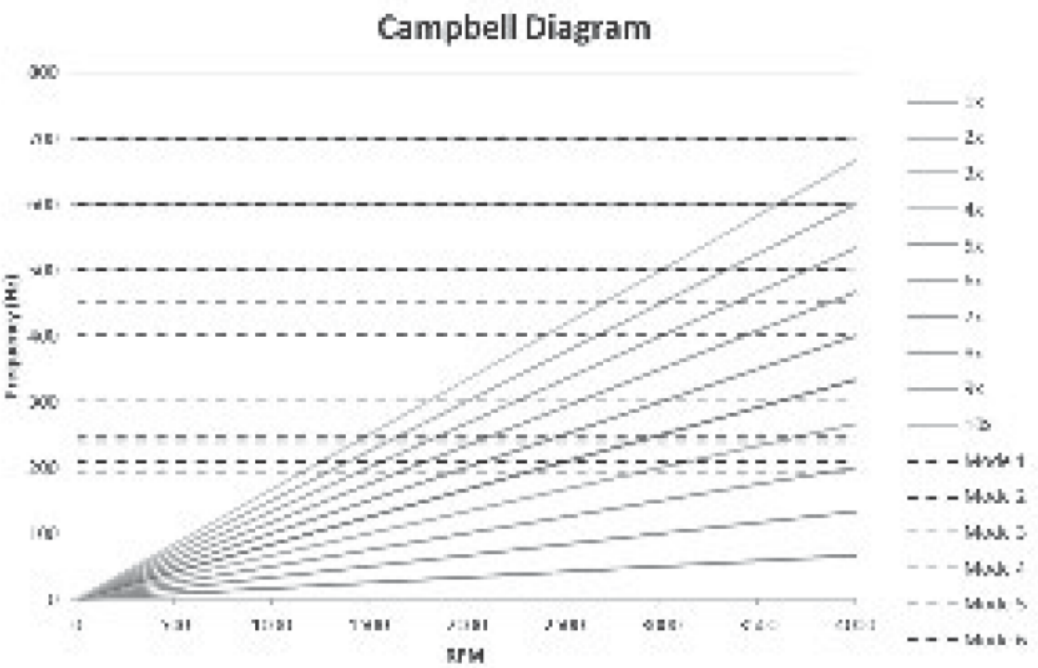

FIG. 5C

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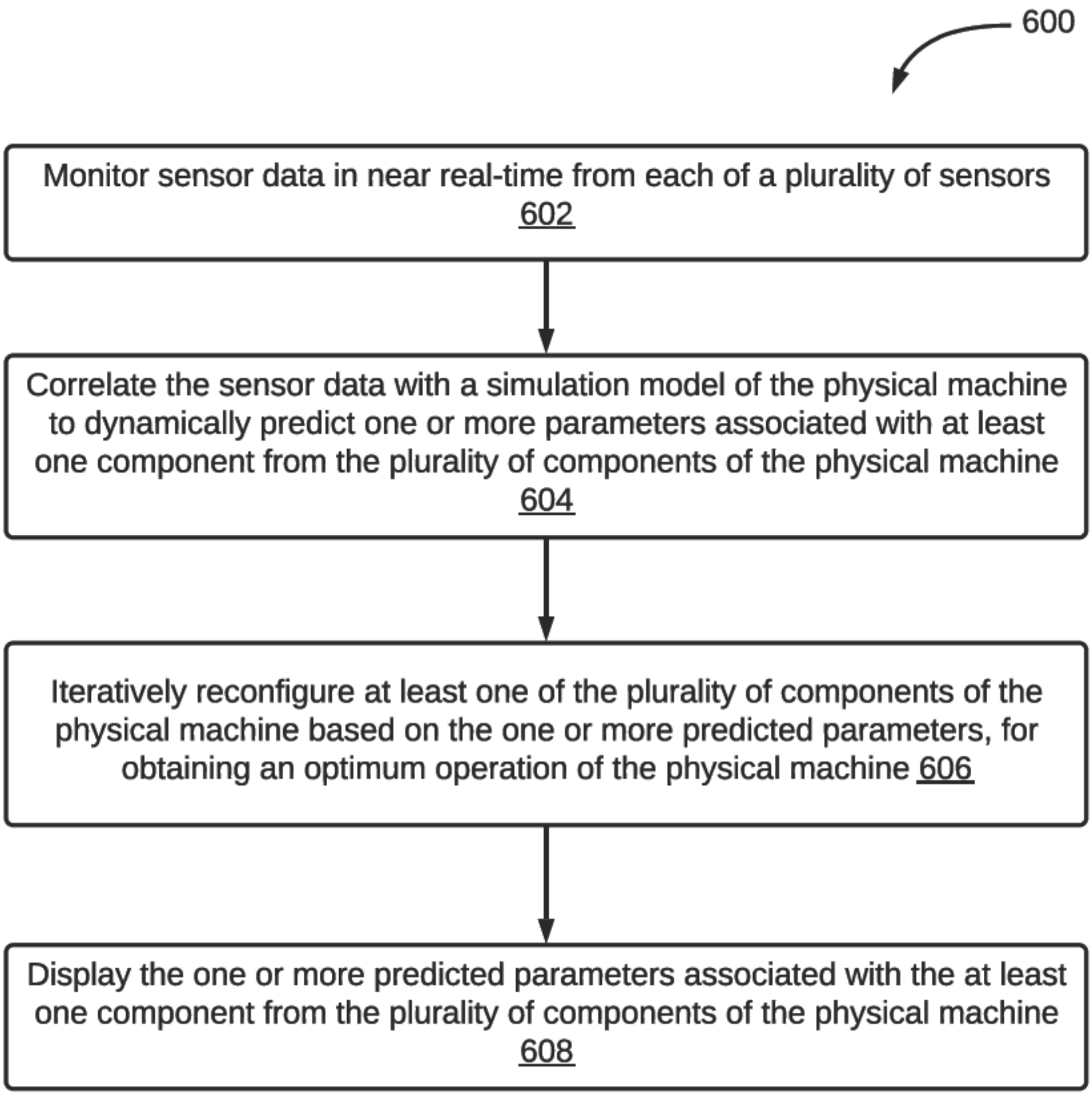

FIG. 6

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