Title: SYSTEM AND METHOD FOR MONITORING AND ANALYZING INDUSTRIAL OPERATIONS

Abstract: An industrial system and method for monitoring and analyzing industrial operations such that data is obtained from one or more sensors of one or more industrial components and transmitted to a master controller as a data stream through a communication network, the transmitted data is captured, copied, and stored for analysis without interfering with the data stream.
Description

SYSTEM AND METHOD FOR MONITORING AND ANALYZING INDUSTRIAL OPERATIONS

Technical Field

[0001] The present invention is directed to monitoring and analyzing industrial operations and more specifically, to a system and method for monitoring and analyzing industrial operations such that data is captured, copied, and stored for analysis.

Background

[0002] In the past machines were self-contained mechanical devices generally having multiple parts that were controlled using various mechanical control systems. As machines developed, electronic control systems have replaced or supplemented the mechanical control systems and now many control systems operate apart from the machine itself utilizing communication systems that operate through one or more communication networks to transfer control commands from a controller, such as a programmable logic control system (PLC), to the machine. Communication systems typically operate to transfer information, such as data and data packages, for review and storage in various device databases and often include data derived from sensors, controllers and other sources that operate together to monitor the operation of such machines.

[0003] As computational capabilities of large computer systems have become faster and cheaper, there is a benefit to being able to analyze industrial systems containing one or more machines or components on a macro scale. While a failure in most industrial operations are not life threatening, a component or system stoppage, such as for example with a packaging line, can result in thousands of dollars of lost production. Accordingly, for industrial systems, it is desirable to do predictive
analysis on a single industrial system to predict when similar systems or system components need to receive maintenance or servicing prior to expected failure. Many industrial systems, which often incorporate one or more components operating within a network, would also benefit by having predictive analytics incorporated into the systems. However, many industrial systems operating in a network have been in continuous operation for many years and operators are hesitant or unwilling to change the PLC programming controlling such systems. Therefore, it would be desirable to be able to monitor and analyze industrial operations comprising one or more industrial components operating within a network without having to reprogram or modify existing control programs.

[0004] Communication between various industrial components within a network now typically operate at a sub-millisecond level and millions of characters of data per second are exchanged without the need of human interaction. For network developers, it would be desirable to monitor such communication and data being transferred and exchanged between the industrial components operating within a communication network. Various systems have been developed for providing analytics to such industrial networks. One method that has been utilized is to monitor event-based data from a human machine interface (HMI) or open platform communications (OPC) tags. When the state of a tag changes, a monitor reflects that an error occurred. By placing the event-based data into a historian program and analyzing it over time, it is possible to determine what errors were occurring most often. This event and status based system is considered low risk because it only requires reprogramming of the HMI screens and not the reprogramming of the PLC. Unfortunately, such event-based monitoring and predictive systems are limited by using data after an error has occurred and not data generated just prior to and during
an error. Other monitoring systems, for example the free and open-source packet analyzer known as WIRESHARK, have been developed for network troubleshooting, analysis, software and communications protocol development, and education. In operation, such systems monitor network communication and to allow users to pick out specific types of data (data packets) and display all the communication traffic addressed to one of the interface’s configured addresses. However, the systems are not always sufficient to see all network traffic. Further, the systems do not operate to receive data and place the data in a query-able database necessary for performing detailed analysis, such as a predictive analysis.

[0005] Another problem with systems that monitor network communication and obtain data being transferred in a data stream is that such systems operate to interact with the data stream to collect and store data. This interaction often interrupts, disturbs or interferes with the data stream and with data being transmitted to and from various industrial components and to and from a master controller. Further, such systems do not operate to convert data, such as Common Industrial Protocol data, being transmitted through a communications network into a query-able format and stored in a query-able database. Often such systems operate using an "update-in-place" methodology in which a performer consumes the data as it detects the data. The performer captures data and updates the data stored in the database by replacing (overriding) the existing stored data. Accordingly, since the data stored in the database is constantly being replaced with new current data, such systems are unable to perform analysis using past or historical data in order to make a predictive analysis.

[0006] Until now, in order to monitor industrial systems and obtain and store data for predictive analysis, the PLC programming controlling the industrial system
would require modifying or creating and/or installing new programming. This would often require upgrading the PLC hardware as well as installing new programming. The upgraded PLC hardware and/or programming will add new and potentially unstable variables that can result in significant loss of time and increase in costs due to system failure or interruption. Thus, for many operations the potential lost time and increase in costs makes such changes in the PLC programming and/or PLC hardware unacceptable.

**Disclosure of the invention**

[0007] The subject invention is a new and novel system and method for monitoring and analyzing industrial operations such that data is obtained from one or more sensors of one or more industrial components and transmitted to a master controller. The transmitted data is copied and stored for analysis without interfering with the transmission of the data to the master controller.

[0008] A preferred embodiment of the invention is a system for monitoring and analyzing industrial operations comprises at least one industrial component having at least one sensor that operates to obtain data on the operation of the at least one industrial component, a communication network that transmits the data to a master controller, a performer that copies the data being transmitted by the communication network without interfering with the data being transmitted to the master controller, and a databank for storing the data copied by the performer.

[0009] Another preferred embodiment of the invention is a system for monitoring and analyzing industrial operations comprising at least one industrial component having at least one sensor that operates to obtain data from the at least one industrial component, at least one component control system that operates to receive the data and to transmit the data in the form of a data stream through a
communication network to a master controller, a performer in communication with the communication network and operates to copy the data from the data stream without impeding the data stream, and wherein the performer further operates to convert the copied data into a query-able format and stores the converted data in a query-able database.

[0010] In a preferred embodiment of the invention, the system further comprises an analyzer that operates to select all or portions of the copied and converted data stored in the query-able database and makes a comparison of the data to reference data and using the comparison to determine if the one or more industrial components are properly performing their desired functions.

[0011] In another preferred embodiment of the invention, the system further comprises an analyzer that operates to select all or portions of the data stored in the query-able database and makes a comparison of the data to reference data and using the comparison to determine if specific elements comprising the one or more industrial components are operating within operating specifications.

[0012] In another preferred embodiment of the invention, the analyzer operates to make comparisons and/or analyze the stored data in the query-able database for a specific industrial component prior to the specific industrial component having an error or a malfunction.

[0013] In another preferred embodiment of the invention the analyzer operates to predict the likelihood or probability of a specific industrial component having an error or a malfunction within a predefined time segment by making a comparison of data for the industrial component prior to sustaining an error or malfunction with data stored in the query-able database for other similar industrial components within a predefined time frame prior to the similar industrial components having an error or a
malfunction and using the comparison, such as by use of fuzzy logic, to make predictions and/or one or more recommendations with regard to the specific industrial component.

[0014] In another preferred embodiment of the invention, the data being transmitted through the communication network is in the form of data packages, whereby metadata is appended to each data packet and whereby the data packets are compressed and bunched together into optimized sized bytes and stored in the query-able database.

[0015] Another preferred embodiment of the invention is a system for monitoring and analyzing industrial operations comprising one or more industrial components each having a component control system and one or more sensors that operate to obtain data related to the operation of the one or more industrial components, wherein each component control system is in communication with a communication network for transferring the data in the form of data packets to a master controller, wherein the data packets are contained in one or more layers of a protocol architecture and wherein a performer operates to unwrap and copy the data contained within the data packages without impeding the transference of the data packets to the master controller, and further operates to convert the data by a structured query language and stores the data in a query-able database.

[0016] in a preferred embodiment of the invention the performer operates to parcel out data contained in each data package to form one or more sets of data each set having a field, and wherein the performer further operates to convert each set of data by a structured query language by constructing an insert query into each field in each set of data.
In another preferred embodiment of the invention, the system further operates to aggregate the data, print out requested reports regarding the data, run a mathematical analysis (such as a statistical or predictive analysis) of the data, and uses the mathematical analysis to make predictions and/or recommendations.

Another preferred embodiment of the invention is a system for monitoring and analyzing industrial operations and comprises one or more industrial components each having one or more sensors that operate to obtain data related to the operation of the one or more industrial components, whereby the data is transferred to a master controller; and an analyzer that receives the data and operates to select all or portions of the data and makes a comparison of the data to reference data and determines using the comparison if the one or more industrial components are not properly performing within operating specifications and/or if one or more industrial components are predicted to fail within a predefined time segment. The analyzer further operates to transmit a warning if the one or more industrial components are not performing within operating specifications and/or if the one or more industrial components are predicted to fail within a predefined time segment.

In a preferred embodiment of the invention, the analyzer further operates to make a recommendation with regard to the one or more industrial components based on the comparison.

Various other objects, advantages, and embodiments of the invention will be apparent from the following description, the accompanying drawings, and the appended claims.

**Brief Description of the Drawings**

To provide a more complete understanding of the present invention and further features and advantages thereof, reference is now made to the following
description taken in conjunction with the accompanying drawings, in which:

[0022] FIG. 1 is a schematic diagram of a preferred embodiment of the system of the subject invention showing an exemplary industrial system performing an industrial operation having one or more industrial components each having a component control system that receives data from one or more sensors and transmits the data through a communication network to a master controller, and further showing a performer for copying data being transferred through the communication network without impeding data being transmitted to the master controller;

[0023] FIG. 2 is a schematic diagram of the industrial system of FIG. 1 showing data including communication protocols being transmitted as a data stream to a master controller;

[0024] FIG. 3 is a schematic illustration showing an exemplary communications protocol having a protocol architecture comprising a suite formed having one or more layers that represent various operations and each having one or more specific data related protocols for transport through the communication network;

[0025] FIG. 4 is a schematic illustration showing an industrial component having a component control system in communication with a communication network for transmitting data to a master controller and for transmitting control commands from the master controller to a component control system;

[0026] FIG. 5 is a schematic illustration showing an exemplary performer having a processor for performing performer software and an electronic databank with a query-able database for storing data, both current data and reference data (historical data);
[0027] FIG. 6 is a schematic illustration showing a protocol architecture layer in the form of an encapsulation layer having data to be copied by the performer and formed into data sets and stored in the databank;

[0028] FIG. 7 is a schematic illustration of a data set having an insert query placed within the data set by the performer and stored in a query-able database;

[0029] FIG. 8 is a schematic illustration of another preferred embodiment of the invention whereby the component control systems operate to block together data and compress the blocks of data into an optimal size for transmittal to the master controller through the communications network and which can be copied by the performer for storage in a query-able database of a databank;

[0030] FIG. 9 is a schematic diagram of another exemplary industrial system showing the performer in communication with a human-machine interface (monitor) and an analyzer that operates to analyze data, such as by performing a statistical or predictive analysis, contained within the query-able database;

[0031] FIG. 10 is a schematic diagram showing current data and reference data (such as historical data) being used to make a comparison by the analyzer;

[0032] FIG. 11 is a schematic diagram showing another preferred embodiment of the invention showing an individual data stream and data within the data stream having a metadata tag and a human-machine interface in communication of the data stream;

[0033] FIG. 12 is a schematic diagram showing the performer monitoring data being transmitted through the communications network and sending requests for specific data to one or more industrial components;

[0034] FIG. 13 is an exemplary flow diagram showing methodology of a method for monitoring and analyzing industrial operations to determine or predict if
one or more industrial components are not performing properly or needs or may soon require maintenance;

[0035] FIG. 14 is an exemplary flow diagram showing the methodology of the subject invention illustrating an operator selecting metadata for data that is to be copied for making predictive analysis and for sending a request for data and transmitting the requested data;

[0036] FIG. 15 is an exemplary flow diagram showing the methodology of the subject invention illustrating the forming of blocks of data, compressing the blocks of data and transmitting the blocks of data through the communications network, copying the blocks of data without impeding or interfering or disrupting the data stream, decompressing the blocks of data and performing an analysis using the decompressed blocks of data;

[0037] FIG. 16 is a schematic diagram showing the analyzer in communication with the master controller and transmitting recommendations to the master controller for modifying the operation of the industrial system;

[0038] FIG. 17 is an exemplary flow diagram showing the methodology of the subject invention illustrating the analyzer in communication with the master controller for modifying the operation of one or more industrial components of the industrial system; and

[0039] FIG. 18 is schematic diagram of another preferred embodiment of the invention showing a system comprising one or more industrial components having one or more sensors for obtaining data on the operation of the one or more industrial components and at least one communication network for transmitting the data to a master controller, and an analyzer that operates to analyze the data.
Best Mode for Carrying Out the Invention

[0040] The subject invention is a new and novel system and method for monitoring and analyzing industrial operations such that data is obtained from one or more sensors of one or more industrial components and transmitted to a master controller. The system and method also operates such that the transmitted data is copied, and stored for analysis without interfering with the flow of data (data stream) to the master controller (or other control systems) and is not interrupted or disturbed. Thus, the master controller (or other control systems) can operate without any interruption (or knowledge) caused by the system or method of the subject invention. In a preferred embodiment, the system operates such that data is obtained from one or more sensors of one or more industrial components and transmitted as a data stream through a communication network to a master controller. A performer in communication with the communication network operates to monitor the data stream traveling through the communication network and copies or mirrors data within the data stream without impeding the data stream. It should be understood that as used herein the communication network can be a single network or more than one network cooperating together or independently and which are capable of transmitting information to and from industrial components and/or to and from one or more industrial components and one or more control systems and/or to a databank and/or a cloud storage system. It should also be understood that the communication network can also be in the form of an in-memory, on-disk, on-ship or other such communication method/network. It should be understood that as used herein the master controller can be in the form of a single unit having multiple components such as, but not limited to, one or more processors, one or more memories and memory storage devices, one or more performers, and other like components or can be in the
form of separate units operating at the same or different locations, such as but not limited to edge controllers, that cooperate together along the lines of the subject invention as described herein. Preferably, the copied data is then converted to a Structured Query Language (SQL) or other similar query-able language and stored in a query-able database of a databank. In another preferred embodiment of the invention, the performer includes a processor that operates to select all or one or more portions of data in the database and compares the data to reference data and determines if one or more industrial components or one or more particular component elements are not performing properly or are not properly performing their desired functions. In another preferred embodiment of the invention, the analyzer operates to make a mathematical analysis, such as a predictive analysis, using data from one or more of the industrial components and determines if the industrial component(s) or if one or more component element(s) require or will require maintenance to prevent failure or operational errors occurring in the relative near future, such as in a predefined time period. In a preferred embodiment, in order to speed up the real time analysis, the system operates to copy data in the form of data packets being transferred in a data stream through a communication network, appends a metadata tag to each copied data packet, compresses and bunches the data packets together into network optimized sized bytes and stores them in a query-able database of a databank for future analysis.

[0041] In a preferred embodiment of the invention, the analyzer operates to select all or portions of the data copied by the performer and stored in the query-able database and makes a comparison of the data to reference data and determines using the comparison if an industrial component or an industrial element is properly performing its desired function or functions or operating within (or outside) its
operating specification. In another preferred embodiment of the invention the analyzer operates to perform a mathematical analysis, such as a predictive analysis, by making a comparison of the data copied by the performer for a particular industrial component (or a particular component element) to reference data, such as data obtained from one or more industrial components (or component elements) prior to such components performing an error or having a malfunction. The comparison is then used to predict the probability of the particular component (or the particular component element) having an error or a malfunction during a predefined time period. Preferably, the analyzer transmits a warning and/or transmits a recommendation, such as to a human-machine interface display, prior to the error or malfunction. In a preferred embodiment of the invention, the warning is displayed on the human-machine interface.

[0042] As used herein the term "industrial system" includes manufacturing, assembly, packaging, transporting, and production systems including, but not limited to, manufacturing operations and/or assembly operations and/or packaging, retrieval, storage and/or other systems and/or devices. As used herein the term "industrial operation" includes manufacturing processes, assembly processes, transporting processes, and production processes including, but not limited to, manufacturing and/or assembly processes and/or transporting and/or production processes. As used herein the term "industrial component" refers to one or more individual apparatus or devices, typically having one or more industrial elements that operate to perform an industrial operation. As used herein the term "master controller" refers to a control system such as a proportional-integral-derivative control system (P1D), a distributed control system (DCS) and programmable logic control system (PLC) and their functional successors (i.e. programmer automation controllers, PC
based control, etc., etc.) that regulates, monitors and/or controls the operation of one or more industrial components operating in an industrial system. As used herein the term "component control system" refers to an individual component control system that functions to control the individual operation of an industrial component. It should be understood that the master controller and/or one or more of the individual component control systems can be at the same physical location (i.e., same proximate factory floor or even built into the same processor (such as a chip having a different core)) or at different locations. As used herein, the term "software" refers to any form of programmed machine-readable language or instructions (e.g., object code) that, when loaded or otherwise installed, provides operating instructions to a machine capable of reading those instructions, such as a computer or processor. It should be understood that the software of the present invention can be stored or reside on, as well as be loaded or installed from, one or more floppy disks, CD ROM disks, hard disks or any other form of suitable non-volatile electronic storage media. The software can also be installed by downloading or other form of remote transmission, such as by using Local or Wide Area Network (LAN or WAN)-based, Internet-based, web-based or other remote downloading or transmission methods. As used herein the term "reference data" refers to data, such as but not limited to data for a particular industrial component or component element obtained from a different time segment, or historical data, or data obtained from one or more other industrial components (or one or more other component elements) that are performing the same or similar functions or are the same or similar in design and operation, or operating specifications such as operating or design specifications for the same or similar industrial component (or component element). As used herein the term "current data" refers to data taken in real time or during a defined time
segment (a particular time range that an industrial component is operating) and the
term "historical data" refers to reference data taken during a time segment that is
earlier or prior to the time segment of the current data.

[0043] In a preferred embodiment of the invention an exemplary industrial
system 100, is schematically illustrated in FIGs. 1 and 2, and comprises one or more
industrial components (or nodes) 102 performing a specific task and each having a
component control system 104 that includes component software 200 that functions
to control the operation of the industrial component 102 and to receive instructions
from a master controller 106 through at least one communication network 108. The
component control system 104 for each industrial component 102 further operates to
receive data 202 from one or more sensors 110 and transmits the data 202 as a data
stream 204 (FIG. 2) to the master controller 106 through the communication network
108. The master controller 106 operates to continuously receive data 202 from the
data stream 204 and monitors and controls the overall operation of the industrial
system 100 and the individual industrial components 102 comprising the industrial
system 100. Preferably, data 202, such as data from a plurality of sensors 110 that
operate to obtain various operating measurements from various component
elements 112 of an industrial component 102, are communicated to the component
control system 104 and transmitted to the master controller 106 as a data stream
204 through at least one communication network 108. In one preferred embodiment,
the master controller 106 is a standard automation controller, such as a
programmable logic controller (PLC) that operates using a high-level programming
language to generate control commands that are passed to the various individual
component control systems 104 that are in electrical communication through the
communication network 108, such as by a plurality of cables and wires, or through a
wireless system. It should be understood that the master controller 106 can also
comprise various other computing hardware such as central processing units
(CPU's), graphics processing units (GPU's), digital signal processors (DSP's),
imicroprocessors, field programmable gate arrays (FPGA's), very large scale
integration (VLSI) systems, complex programmable logic devices (CPLD's), or
systems on chips (SOC's), and/or other such data processing and/or control devices.

[0044] In operation, data 202 is transmitted to and from the individual
component control systems 104 and the master controller 106 as a data stream 204
utilizing communication protocols 206 for digital messaging through the
communication network 108 and for exchanging data between various industrial
components 102 and the master controller 106. The communication protocols 206,
such as, but are not limited to, EtherNet/iP, ControlNet, DeviceNet, Profinet, and
Common Industrial Protocol (CIP), operate as the rules for transmitting messages
and/or data 202, such as in the form of data packages, between the various control
systems. It should be understood that other communication protocols can be utilized
and are within the scope of the invention. Component software 200 utilized by the
various industrial components 102 also operate to configure the transmission of the
data 202 such that the transmission is efficient for the particular component 102 and
are within the bounds of the communication protocols 206 for communicating with
the master controller 106.

[0045] In a preferred embodiment, the industrial system 100 utilizes the
communication protocol 206 known as Common Industrial Protocol (CIP) or any
other communication protocol which is generally used for industrial automation
applications. As schematically illustrated in FIG. 3, in a preferred embodiment the
communications protocol 206 has a protocol architecture 208 that includes a suite
formed in layers that represent various operations and have specific functions, each having one or more specific data related protocols for transmitting, receiving and storing data being transferred through the communication network, such as, but not limited to, internal dosed communication networks or external communication networks, such as the Internet. Manufacturing and component data in the form of data packages are transmitted from the various industrial component control systems through the communication network to the master controller where the data is captured and stored in a master control databank. During operation of the industrial system, in a preferred embodiment the master controller operates in real time to monitor the various conditions of the industrial system including the status of the various operations being performed by each industrial component and can operate to adjust the operation of each industrial component or send out a warning, such as to a human-machine interface, in the event the system is not operating properly.

As illustrated in Figs. 1 and 5, the industrial system further comprises a performer in communication with the communication network and includes a processor having performer software, and an electronic databank. The electronic databank preferably includes at least one query-able database, such as a SQL database, a Hadoop database, and other such query-able databases that allow users to easily track, store, search and retrieve data, both current data (data currently being transmitted and copied from the data stream) and reference data, such as historical data gathered (copied) from the data stream traveling along the communication network during an earlier
or a prior time segment for the same or similar industrial components (and/or component elements).

[0047] Referring to the figures and specifically to FIGs. 3, 4 and 6, in a preferred embodiment of the invention one layer 212 of the protocol architecture 208 is in the form of an encapsulation layer 213 whereby data 202 in the form of data packages are wrapped within the encapsulation layer 213 and transported through the communication network 108. In operation, the performer 114 operates to monitor the data 202 traveling through the communication network 108 and copies or mirrors the data 202 contained within the encapsulation layer 213 without impeding the data stream 204. Once copied, the performer software 216 (FIG. 5) operates to de-capsulize or un-wrap the data 202 from the encapsulation layer 213 of the protocol architecture 208 using conventional de-capsulizing software or procedures 300 provided by a communication network's vendor. The performer 114 further operates to conventionally parcel out and store the data 202 in the electronic databank 118 using architecture software or process 302 outlined by the specific protocol architecture specification. This process is continuously repeated until sufficient data 202 has been obtained to form one or more sets of data 222. Each data set 222 is then converted to a Structured Query Language (SQL) or other such query-able language, and stored in the electronic databank 118 as a query-able electronic database 120 using the standard query software or procedures 304 provided by the format vendor(s). For an exemplary illustration, as illustrated in FIG. 7, to convert a set of data 222 into a query-able format for usage in the query-able database 120, the performer 114 would operate to construct an insert query 224 where each data field in the sets of data 222 corresponds to zero or more fields in the query-able database 120 which permits the data 202 contained within the sets of
data 222 to be easily queried. Once the data 202 is in the query-able format and stored in the query-able database 120, an analyzer can be used, as described herein below, such that one can query the data, search and aggregate the data, run mathematical analysis of the data, such as a statistical or predictive analysis, and print out reports with regard to the data and the mathematical analysis, use the data in another business process, and other such uses. It should be understood that the reports can be digital reports and/or graphical, charts, tables, spreadsheets and other such means for displaying data and can be in the form of paper or electronically displayed, such as on a human-machine interface, computer screen or other conventional display systems and devices.

[0048] It should also be understood that depending on the desired amount of data 202 to be copied and stored, the analyzer 122 (FIGs. 9 and 10), the query-able database 120 could be overloaded or could operate relatively slowly. Accordingly, in another preferred embodiment of the invention, as illustrated in FIG. 8, the component software 200 of the individual component control systems 104 are programmed to form the data 202 into blocks 226 and compress the blocks of data 202 into an optimal size and transmitted to the master controller 106 through the communications network 108. The performer 114 can then operate to monitor the blocks 226 of data 202 traveling through the communication network 108 and copies or mirrors the data blocks 226 within the data stream 204 without impeding the data stream 204 and stores the data blocks 226 in the query-able electronic database 120 as a group of records. Accordingly, multiple blocks 226 of data 202 can be copied in an efficient manner to minimize the likelihood of overwhelming the performer 114 or the query-able database 120 as well as improving processing speed. It should be understood that the performer 114 can also operate to decompress the blocks 226 of
data 102 and store them in the query-able database 120 as a group of records 228. It should also be understood that in order to further increase the speed of processing the performer 114 can operate to decompress multiple blocks 226 of data 102 at one time.

[0049] Referring to FIGs. 1, 9 and 10, the performer 114 is in communication with an analyzer 122 having analyzer software and/or firmware 230 that operates to analyze data 202 (such as by performing a statistical or predictive analysis) contained within the query-able database 120 of the electronic databank 118. In a preferred embodiment, current data 218 that is copied from the data stream 204 and stored in the query-able database 120 (such as data from one or more sensors 110 monitoring the operation of one or more industrial components 102) is compared to reference data 220. For an exemplary illustration, current data 218 of a manufacturing operation being performed by an industrial component 102 is copied by the performer 114 and stored in a query-able database 120 for that industrial component 102. The analyzer 122 operates such that a comparison 239 is made of the current data 218 to reference data 220 for that industrial component 102 (reference data such as historical data from other similar industrial components (or component elements)). In the event the current data 218 is outside predetermined normal operating specifications (tolerances) 232, a warning 234 is issued prior to failure of the industrial component (or a component element). In another exemplary illustration, current data 218 of a manufacturing operation being performed by an industrial component 102 is copied by the performer 114 and stored in a query-able database 120 for that industrial component. The analyzer 122 operates such that a comparison 239 is made of the current data operating parameters 238 to operating parameters 236 of reference data 220 for that industrial component (or component
element or other similar industrial components (or component element)). It should
be understood that such operating parameters 236 of the reference data 220 are
parameters that were reached just prior to an industrial component failure (data from
sensors just prior to such failure). In the event current operating parameters 238
from an industrial component 102 begins to approach the operating parameters 236
within a predefined operating tolerance 232, a warning 234 is generated and
transmitted to an operator, or displayed on a human-machine interface 128, that the
industrial component or a component element is near failure, requires servicing, or is
not performing properly. For another exemplary illustration, current data 218 of a
manufacturing operation being performed by an industrial component 102 is copied
by the performer 114 and stored in a query-able database 120 for that industrial
component. The analyzer 122 operates such that a comparison is made of the
various operating parameters 238 of the current data 218 to corresponding operating
specifications 232 to determine if the difference between the current operating
parameters 238 of the current data 218 and the reference data 220 operating
specifications 237 (FIG. 9) are outside allowable predetermined tolerances 232. In
the event the difference between the parameters 238 of the current data 218 and the
operating specifications 237 are outside (or approaching being outside) the
predetermined tolerances 232, a warning 234 is generated and transmitted to an
operator or to human-machine interface 128 for display.

[0050] In a preferred embodiment of the invention, as illustrated in FIGs. 1, 9
and 11, the analyzer 122 includes or is in communication with a human-machine
interface 124 that allows an operator to select what metadata tag 240 to select in
copying data 202 from the data stream 204. Preferably, the human-machine
interface 124 includes interface software 242 that communicates and cooperates
with the performer software 216 (FIG. 5) and is an interactive, menu and event
driven system that further cooperates with an interface display 126 for creating and
using conventional type of prompt, dialog, and entry windows 128 to guide a user to
enter information. Thus, the industrial system 100 provides an interactive
communications interface for facilitating communications and information exchange
between the human-machine interface 124 and the analyzer 122 and the performer
114. It should be understood that an operator can select what metadata tags 240 to
utilize in selecting data 202 that closely aligns with the needs for the analyzer 122 to
make a predictive analysis. In addition, by selectively identifying the metadata tags
240 to be used, a single analyzer 122 can be used for multiple industrial systems.

[0051] It should now be apparent that the system and method for monitoring
and analyzing industrial operations permits predictive analysis to be conducted by
performing data queries and examining for recurring patterns and performing
conventional statistical analysis using such recurring patterns to predict the
probability of similar events happening in the future. For an exemplary illustration,
data showing that a temperature reading on an industrial component began to show
an increase over time prior to a bearing on a gear began to fail. By determining this
temperature increase is statistically predictive, the analyzer can be programmed to
monitor new data and identify such temperature increase thereby identifying and
providing a warning to an operator that the industrial component associated with the
new data may be experiencing a near future bearing failure. Accordingly,
maintenance can be performed on the industrial component prior to such failure.

[0052] In a preferred embodiment of the invention, as illustrated in FIG. 12,
the performer 114 further operates to monitor the communication network 108, such
as monitoring metadata tags 240 every millisecond, for identifying specific data
In the event the performer 114 has not identified and copied certain desired data 202 within a preset period of time (time segment), the performer 114 can send requests (pings) 242 to one or more individual component control systems 104 through the communication network 108 directing the targeted component control system 104 to transmit the requested data 244 through the communication network 108. In another preferred embodiment, the performer 114 can further operate to send such requests 242 to identify if data loss or errors are occurring in the data stream 204. In the event of an error or data loss is identified a warning 246 can be displayed on the interface display 126 of the human-machine interface 124 allowing an operator to investigate and correct the problem.

[0053] Another preferred embodiment of the invention is a method for monitoring and analyzing industrial operations is illustrated in FIG. 13 and comprises the steps of using one or more sensors to take measurements or collect data on one or more industrial components or component elements of at least one industrial component (step 400) and transmitting the data as a data stream through at least one communication network to a master controller (step 402). A performer operates to copy or mirror the data in the data stream without disturbing, impeding, interfering or disrupting the fluid stream (step 404) and stores the data in a query-able database (step 406). An analyzer operates to compare the copied data to reference data (step 408) such as historical data or stored operating parameters or operating specifications and based on the comparison determines if the copied data is outside predetermined or defined operating specifications (tolerances) (step 410). In the event the copied data is outside the predetermined or defined operating specifications (tolerances), the analyzer transmits a warning (step 412). In another preferred embodiment of the invention, as illustrated in FIG. 14, the method
comprises the step of analyzing the copied data and comparing it to reference data to determine if the industrial component requires maintenance (step 414). In another preferred embodiment of the invention the method includes the step of an operator selecting metadata (tags) for selecting data to be copied that closely aligns with the needs for the analyzer in making a predictive analysis (step 416). In another preferred embodiment, the method includes the step of monitoring data in the data stream (step 418) and the performer sending one or more requests for data to a component control system (step 420) and the component control system transmitting the requested data through the communications network (step 422).

[0054] In another preferred embodiment of the invention, as illustrated in FIG. 15, the component software of the individual component control systems are programmed to form the data into blocks of data (step 424) and compress the blocks of data into an optimal size (step 426) and transmits to the master controller through the communications network (step 428). The performer operates to monitor the blocks of data traveling through the communication network and copies or mirrors the data blocks within the data stream without impeding, interfering or disrupting the data stream (step 430) and stores the data blocks in the query-able electronic database (step 432) as a group of records. The performer then operates to decompress the blocks of data (step 434) and uses the data for performing a predictive analysis (step 436).

[0055] In a preferred embodiment of the invention, as illustrated in FIGs. 16 and 17, the analyzer 122 further operates to make one or more recommendations 244 concerning the operation of an industrial component 102 (or component element 112). For a non-limiting exemplary illustration, current data 218 is compared to a reference data 220 (step 500) and using conventional mathematical analysis
program 246, such as statistical analysis, a prediction analysis can be made or calculated as to the likelihood that the industrial component 102 (or component element 112) being evaluated will have an error or a failure within a defined time segment (step 502) (such as selected by the system user or manufacturer). Further, in a preferred embodiment of the invention, the analyzer 122 operates in conjunction with the master controller 106 to make recommendations, such as by use of fuzzy-logic, and to modify the operation of the industrial system 100 based on the recommendations, such as by slowing down or speeding up the operation of the various industrial components 102 or to activate or deactivate various industrial components 102 thereby allowing an operator to perform maintenance or repairs to one or more industrial components (or component elements) that are predicted to fail (step 504). Thus, in a preferred embodiment the analyzer operates to make a comparison of reference data for one or more industrial components that have sustained an error or malfunction with data copied by said performer for said at least one industrial component prior to having an error or malfunction and using conventional mathematical analysis operates to make recommendations with regard to at least one industrial component based on the comparison and transmits the recommendations (such as modify the industrial system) to allow correction or to correct or allow corrections to be made to one or more of the industrial components.

[0056] Referring to FIG. 17, another preferred embodiment of the system 100 is shown whereby one or more industrial components 102 having one or more component elements 112 and one or more sensors 110 in communication with a master controller 106 through one or more communication networks 108. Data 202 (such as various measurements of one or more component elements 112) obtained by the sensors 110 is transmitted to the master controller 106 through the one or
more communications networks 108. An analyzer 122 in communication with the
master controller 106 operates to receive the data 202 directly through the master
controller 106. It should be understood, however that the analyzer can receives the
data 202 directly from the communication network 108 or through another
cOMPONENT, such as a performer as previously described herein. The analyzer 122
includes analyzer software 230 (FIG. 9) that operates to select all or portions of the
data 202 and makes a comparison 239 of the data 202 to reference data 220 and
determines using the comparison 239 if the one or more industrial components 102
(or one or more component elements 112) are properly performing within predefined
tolerances or operating specifications 232. If it is determined that one or more
industrial components 102 (or one or more component elements 112) are not
performing within predefined tolerances or operating specifications 232, the analyzer
122 (or the master controller 106) operate to send a warning 234 which is displayed
on a human-machine interface 128. In another preferred embodiment of the
invention, as illustrated in FIG. 16, the analyzer 122 further operates to make
recommendations 244 concerning the operation of an industrial component 102 (or
component element 112). For a non-limiting exemplary illustration, current data 218
is compared to a reference data 220 and using conventional mathematical analysis
program 246, such as statistical analysis, a prediction analysis can be made or
calculated as to the likelihood that the industrial component 102 (or component
element 112) being evaluated will have an error or a failure within a defined time
segment. Further, in a preferred embodiment of the invention, the analyzer 122
operates in conjunction with the master controller 106 to modify the operation of the
industrial system 100, such as by slowing down or speeding up the operation of the
various industrial components 102 or to activate or deactivate various industrial
components 102 thereby allowing an operator to perform maintenance or repairs to one or more industrial components (or component elements) that are predicted to fail. Thus, in a preferred embodiment the analyzer operates to make a comparison of reference data for one or more industrial components that have sustained an error or malfunction with data copied by said performer for the at least one industrial component prior to having an error or malfunction and using conventional mathematical analysis operates to make recommendations with regard to the at least one industrial component based on the comparison and transmits the recommendations (such as modify the industrial system) to allow correction or to correct or allow corrections to be made to one or more of the industrial components. It should be understood that the individual components, such as, but not limited to, a master controller, performer, analyzer and human-machine interface can be separate components in electrical communication with each other or can be incorporated into a single component. It should also be understood that an operator can input information or instructions directly into the performer and/or analyzer or can input information or instructions into the performer and/or analyzer using the human-machine interface. For a non-limiting illustrative example, an operator can provide instructions (such as programming instructions) directing what data from the data stream is to be copied and stored by the performer. For another non-limiting illustrative example, an operator can instruct the analyzer what mathematical analysis is to be performed and/or the form of report to be generated by the system. In another non-limiting illustrative example, the analyzer, master controller and the human-machine interface can be in communication such that recommendations generated by the analyzer can be directly communicated to the master controller which operates to automatically respond to the recommendation, such as speed up
or slowing down one or more operations or to remove and/or substitute an industrial component or other modification to the industrial system. In another embodiment the recommendations can be communicated to the human-machine interface for display and review by an operator thereby allowing the operator to implement one or more recommendations.

[0057] It should also now be apparent that the system and method for monitoring and analyzing industrial operations of the subject invention provides a structured methodology and design that is new and novel but is not limited to the specific design of the system. Although the foregoing invention has been described in some detail for purposes of clarity of understandings, it will be apparent that certain changes and modifications may be practiced within the scope of the appended claims. Accordingly, it should also now be apparent that the various embodiments presented can be easily modified while keeping within the scope and spirit of the subject invention. It should also be understood that the present disclosure is to be considered as exemplary of the principals of the invention and is not intended to limit the invention to the embodiments and the specific examples illustrated and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalents of the descriptions and examples contained herein.
Claims

1. An industrial system for monitoring and analyzing industrial operations comprising:
   at least one industrial component that operates to obtain data on said at least one industrial component;
   a communication network for transmitting said data to a master controller;
   a performer for copying said data being transmitted by said communication network without interfering with said data being transmitted to said master controller; and
   a databank for storing said data copied by said performer in a query-able database.

2. The industrial system of Claim 1 further comprising an analyzer that operates to select all or portions of said data copied by said performer and stored in said query-able database and makes a comparison of said data to reference data and determines using said comparison if said at least one industrial component is properly performing within operating specifications.

3. The industrial system of Claim 1 further comprising an analyzer that operates to select all or portions of said data copied by said performer and stored in said query-able database and makes a comparison of said data to reference data and using said comparison to determine if specific elements comprising said at least one industrial component is operating within operating specifications.
4. The industrial system of Claim 1 further comprising an analyzer that operates to analyze said data copied by said performer and stored in said query-able database prior to said at least one industrial component having an error or malfunction.

5. The industrial system of Claim 1 further comprising an analyzer that operates to analyze said data copied by said performer and stored in said query-able database prior to said at least one industrial component having an error or malfunction and further operates to determines the possibility that an error or malfunction may occur and if the possibility is more than a predetermined level, said analyzer transmits a warning to a human-machine interface.

6. The industrial system of Claim 1 further comprising an analyzer that operates to make a comparison of historical data for one or more industrial components that have sustained an error or malfunction with data copied by said performer for said at least one industrial component prior to having an error or malfunction and operates to make recommendations with regard to said at least one industrial component based on said comparison.

7. The industrial system of Claim 1 wherein said data being transmitted through said communication network is in the form of data packages, whereby metadata is appended to each data packet and whereby said data packets are compressed and bunched together into optimized sized bytes and stored in said query-able database.
8. An industrial system for monitoring and analyzing industrial operations comprising:

at least one industrial component having at least one sensor that operates to obtain data from at least one sensor;

at least one component control system that operates to receive said data and to transmit said data in the form of a data stream through a communication network to a master controller;

a performer in communication with said communication network and operates to copy said data from said data stream without impeding the data stream;

wherein said performer further operates to convert said data copied by said performer into a query-able format and stores said converted data in a query-able database.

9. The industrial system of Claim 8 further comprising an analyzer that operates to select all or portions of said data copied by said performer and stored in said query-able database and makes a comparison of said data to reference data and determines using said comparison if said at least one industrial component is performing within operation specifications.

10. The industrial system of Claim 8 further comprising an analyzer that operates to select all or portions of said data copied by said performer and stored in said query-able database and makes a comparison of said data to reference data and using said comparison to determine if specific elements comprising said at least one industrial component is operating within operating specifications.
11. The industrial system of Claim 8 further comprising an analyzer that operates to analyze said data copied by said performer and stored in said query-able database prior to said at least one industrial component having an error or malfunction.

12. The industrial system of Claim 8 further comprising an analyzer that operates to analyze said data copied by said performer and stored in said query-able database prior to said at least one industrial component having an error or malfunction and further operates to determines the possibility that an error or malfunction may occur and if the possibility is more than a predetermined level, said analyzer transmits a warning to a human-machine interface.

13. The industrial system of Claim 8 further comprising an analyzer that operates to make a comparison of historical data for one or more industrial components that have sustained an error or malfunction with data copied by said performer for said at least one industrial component prior to having an error or malfunction and operates to make recommendations with regard to said at least one industrial component based on said comparison.

14. The industrial system of Claim 8 wherein said data being transmitted through said communication network is in the form of data packages, whereby metadata is appended to each data packet and whereby said data packets are compressed and bunched together into optimized sized bytes and stored in said query-able database.
15. The industrial system of Claim 8 wherein said data being transmitted through said communication network is in the form of data packages, whereby metadata is appended to each data packet and whereby said data packets are compressed and bunched together into optimized sized bytes and stored in said query-able database.

16. An industrial system for monitoring and analyzing industrial operations comprising:

   one or more industrial components each having one or more sensors that operate to obtain data related to the operation of said one or more industrial components whereby said data is transferred to a master controller;

   an analyzer that receives said data and operates to select all or portions of said data and makes a comparison of said data to reference data and determines using said comparison if said one or more industrial components are properly performing within operating specifications and/or if said one or more industrial components are predicted to fail within a predefined time segment;

   wherein said analyzer further operates to transmit a warning if said one or more industrial components are not performing within operating specifications and/or if said one or more industrial components are predicted to fail within a predefined time segment.

17. The industrial system of Claim 16 wherein said analyzer further operates to make a recommendation with regard to said one or more industrial components based on said comparison.
18. The industrial system of Claim 16 whereby said data being transferred to said master controller is in the form of data packages, whereby metadata is appended to each data packet and whereby each data packet is compressed and bunched together into optimized sized bytes and stored in a query-able database.

19. The industrial system of Claim 16 whereby said data prior to being transferred to said master controller is in the form of data packages, whereby each data packet is compressed and bunched together into blocks.

20. The industrial system of Claim 16 wherein if additional is require by said analyzer, one or more requests are sent to one or more industrial components directing said one or more industrial components to transmit additional data.
Fig. 2

DATA 202

COMMUNICATION PROTOCOLS 206

MASTER CONTROLLER 106

MASTER CONTROL DATABANK 112

Line 204
FIG. 8

DATA BLOCK
226

DATA
202

DATA
202

DATA
202

PERFORMER
114

RECORDS
228

MASTER CONTROLLER
106
FIG. 13

USING SENSOR(S) TO TAKE MEASUREMENTS OR COLLECT DATA OF THE OPERATION OF AN INDUSTRIAL COMPONENT
STEP 400

TRANSMIT DATA TO A MASTER CONTROLLER
STEP 402

COPY OR MIRROR DATA
STEP 404

STORE COPIED DATA (CURRENT DATA) IN QUERY-ABLE DATABASE
STEP 406

COMPARE COPIED DATA (CURRENT DATA) TO A REFERENCE DATA (HISTORICAL DATA AND/OR OPERATING PARAMETERS AND/OR SPECIFICATIONS
STEP 408

DETERMINE IF COPIED DATA (CURRENT DATA) IS OUTSIDE REFERENCE DATA (STEP 410

BASED ON REFERENCE DATA AND COPIED DATA (CURRENT DATA), DETERMINE IF MAINTENANCE SHOULD BE PERFORMED ON INDUSTRIAL COMPONENT
STEP 414

IF OUTSIDE REFERENCE DATA OPERATING PARAMETERS OR SPECIFICATIONS, SEND WARNING
STEP 412
FIG. 14

14/18

OPERATOR SELECTING METADATA OF DATA TO BE COPIED FOR MAKING PREDICTIVE ANALYSIS
STEP 416

MONITORING DATA STREAM FOR DATA
STEP 418

SEND REQUEST TO COMPONENT CONTROL SYSTEM FOR DATA
STEP 420

COMPONENT CONTROL SYSTEM SENDS REQUESTED DATA TO PROFORMER
STEP 422
FORMING BLOCKS OF DATA (CURRENT DATA) STEP 424

COMPRESS DATA BLOCKS INTO OPTIMAL SIZE STEP 426

TRANSMIT DATA THROUGH COMMUNICATIONS NETWORK STEP 428

COPY OR MIRROR DATA BLOCKS WITHOUT IMPEDING, INTERFERING OR DISRUPTING DATA STREAM STEP 430

STORE COPIED (CURRENT DATA) IN A QUERY-ABLE DATABASE STEP 432

DECOMPRESS BLOCKS OF DATA STORED IN QUERY-ABLE DATABASE STEP 434

PERFORM ANALYSIS USING DECOMPRESSED BLOCKS OF DATA STEP 436
FIG. 17

ANALYZER MAKES COMPARISON OF CURRENT DATA TO REFERENCE DATA
STEP 500

USING MATHEMATICAL ANALYSIS TO CALCULATE OR PREDICT LIKELIHOOD OF INDUSTRIAL COMPONENT (OR COMPONENT ELEMENT) FAILURE
STEP 502

ANALYZER IN CONJUNCTION WITH MASTER CONTROLLER MODIFIES OPERATION OF INDUSTRIAL SYSTEM
STEP 504
FIG. 18

HUMAN-MACHINE INTERFACE 128

ANALYZER 122

MASTER CONTROLLER 106

DATABASE 112

DATA 202

234
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - G06F 11/00 (2017.01)
CPC - G05B 23/02; G06Q 10/06; G05B 221/913; G06Q 10/10; H05B 37/0245; G06F 11/3447; G06F 2201/88; G05B 23/02; G06F 11/2257; G07C 3/00; G05B 23/0221; G05B 23/024

According to the International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
See Search History Document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
See Search History Document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
See Search History Document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>US 2007/0259706 A1 (GALT et al.) 27 December 2007 (27.12.2007), entire document, especially para [0015], [0038], [0044], [0051], [0052], [0054], [0057], [0059], [0070]</td>
<td>2-6, 9-20</td>
</tr>
<tr>
<td>Y</td>
<td>US 9,124,909 B1 (WILLIS) 01 September 2015 (01.09.2015), col 2, In 7-13</td>
<td>7-15, 18, 19</td>
</tr>
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Further documents are listed in the continuation of Box C.

* Special categories of cited documents:
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Date of the actual completion of the international search
3 April 2017 (03.04.2017)

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