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(54) **DIAGNOSTICS DATA COLLECTION AND ANALYSIS METHOD AND APPARATUS**

Related U.S. Application Data

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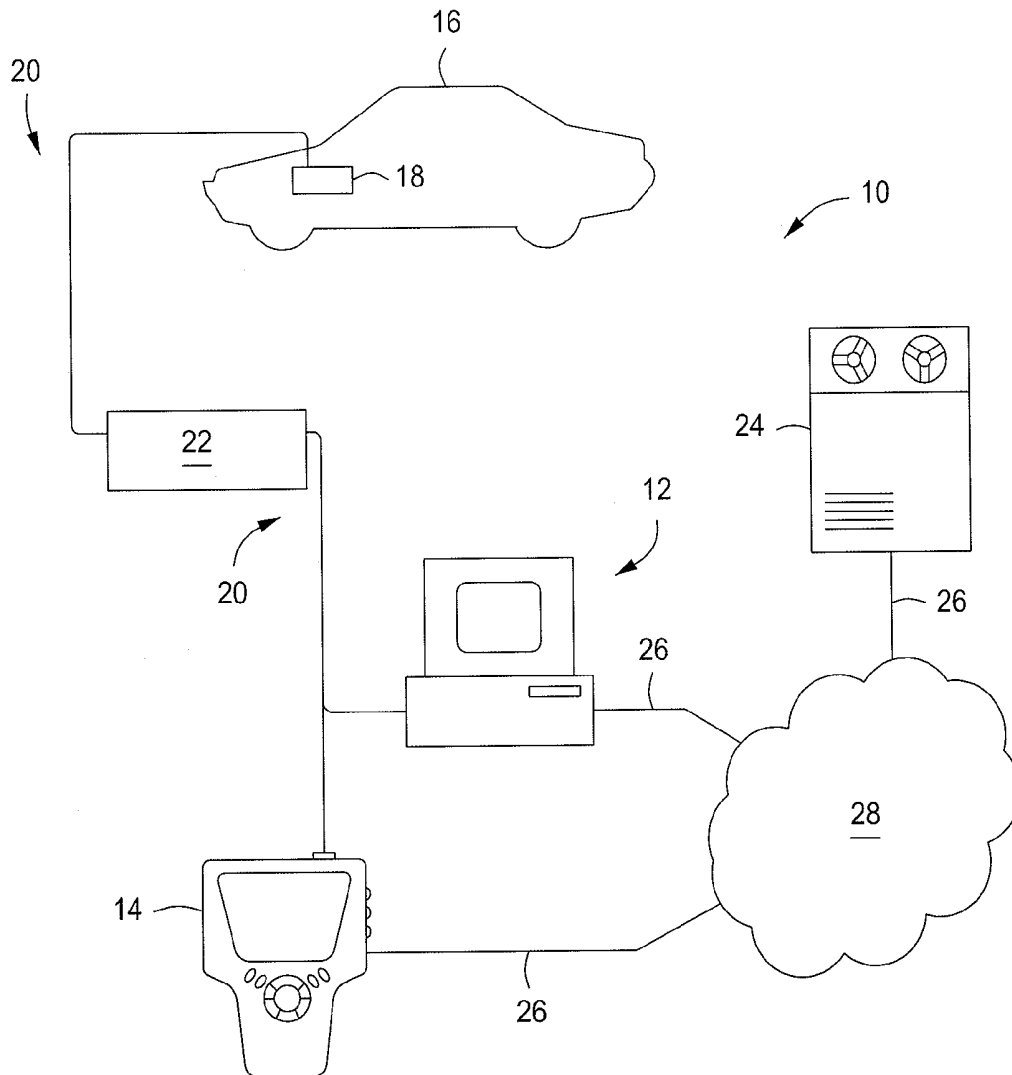
(57) **ABSTRACT**

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A medical diagnostic data collector/analyzer compiles historical vehicle diagnostic data, including measured vital signs from a number of different people from a variety of population types, and performs statistical analyses on various vital sign combinations to establish ranges corresponding to healthy individuals and various disease conditions.

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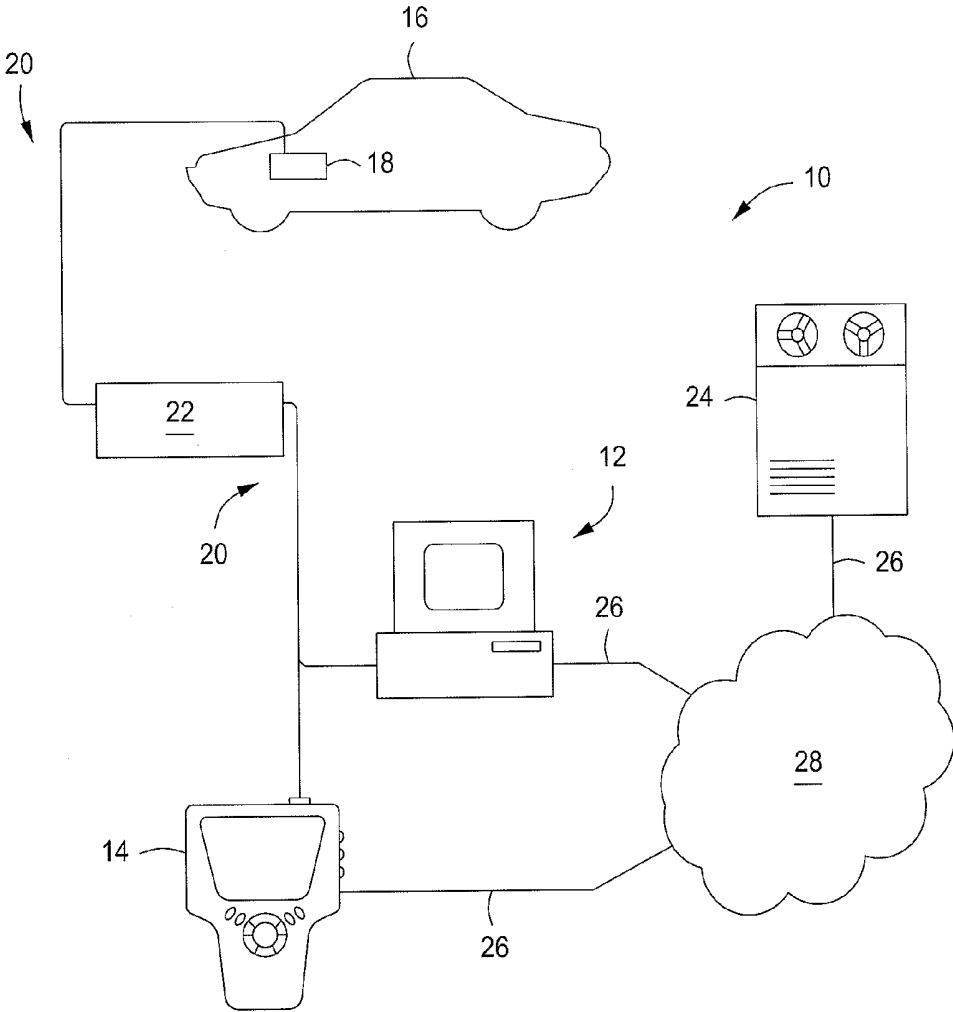


FIG. 1

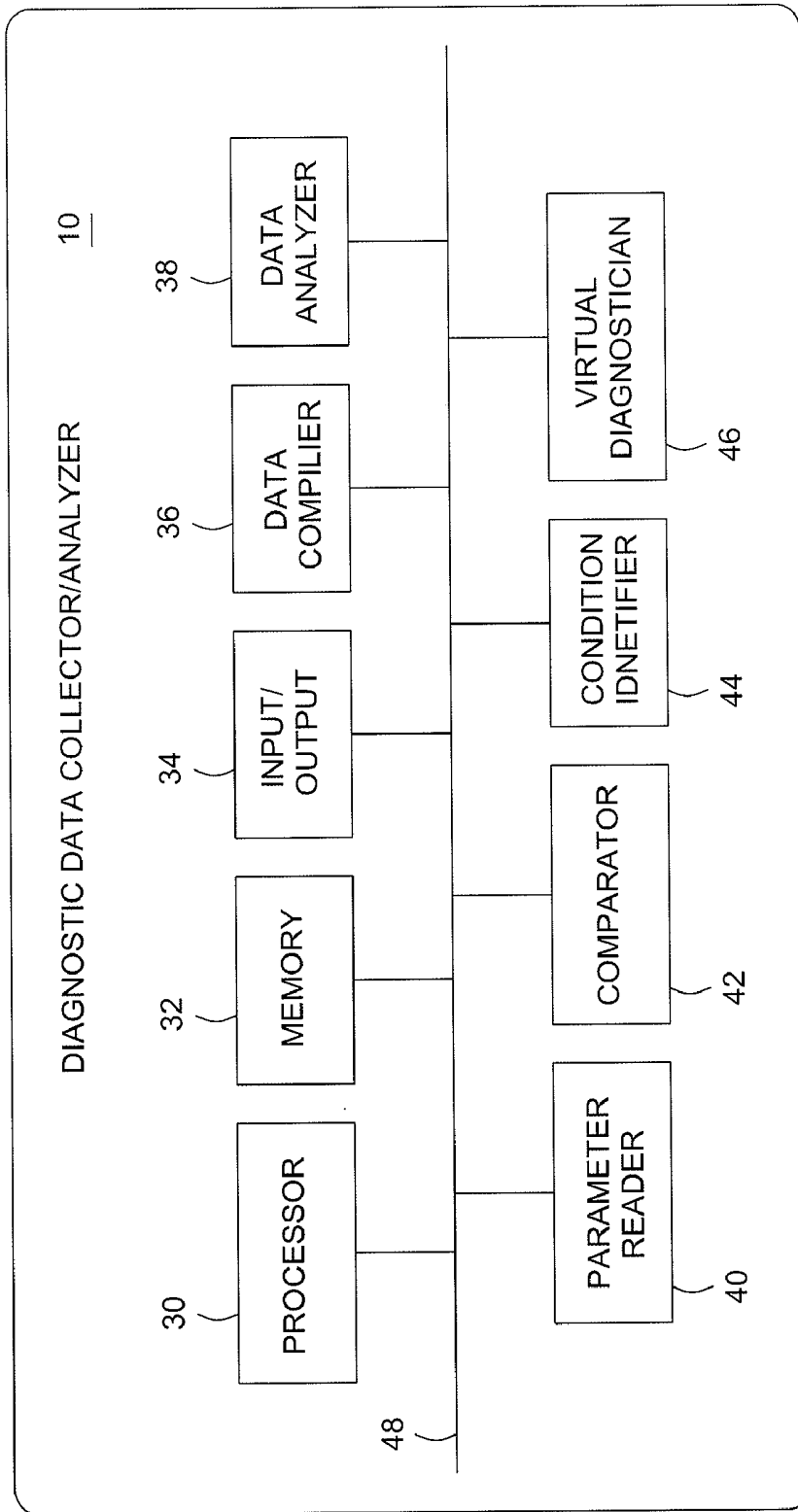


FIG. 2

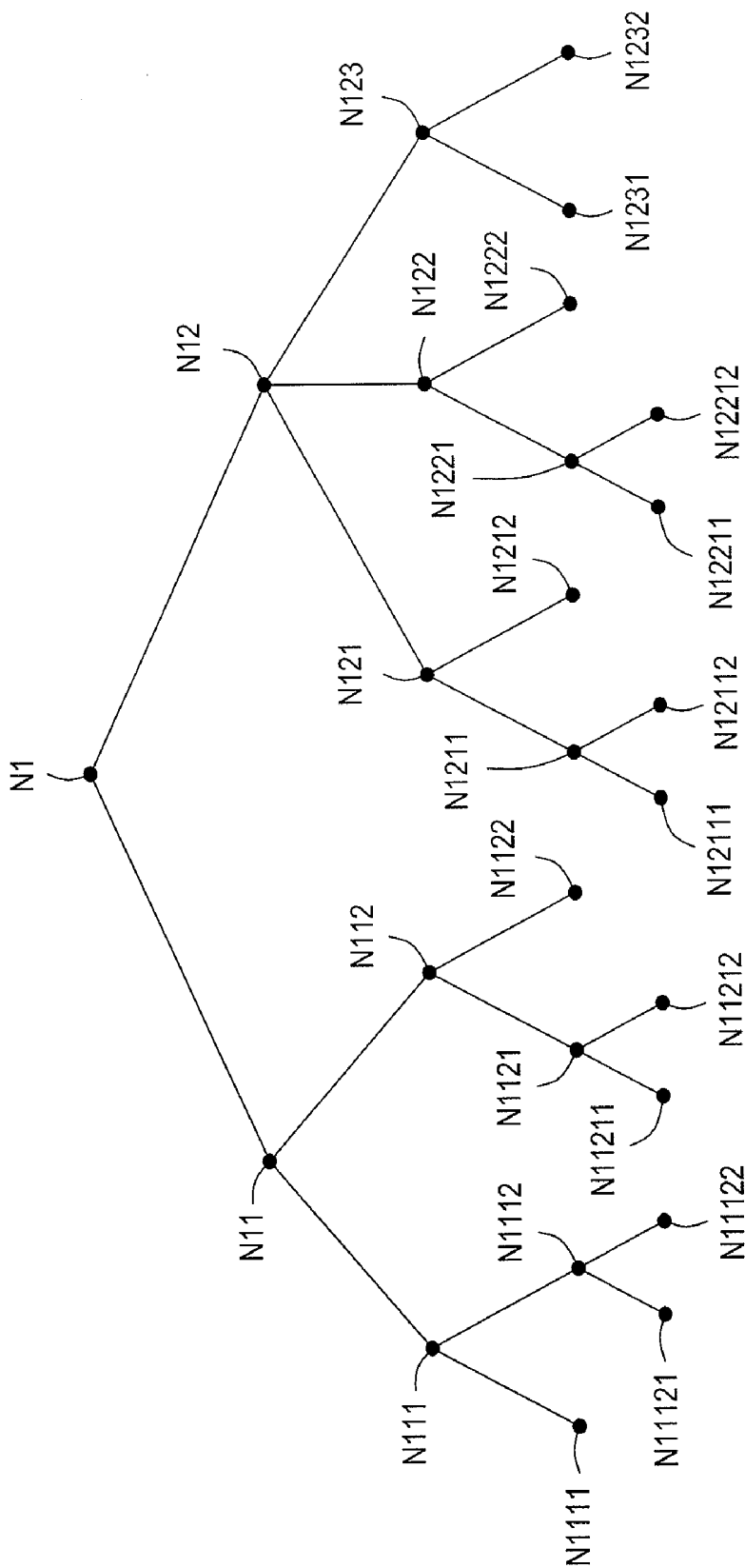


FIG. 3

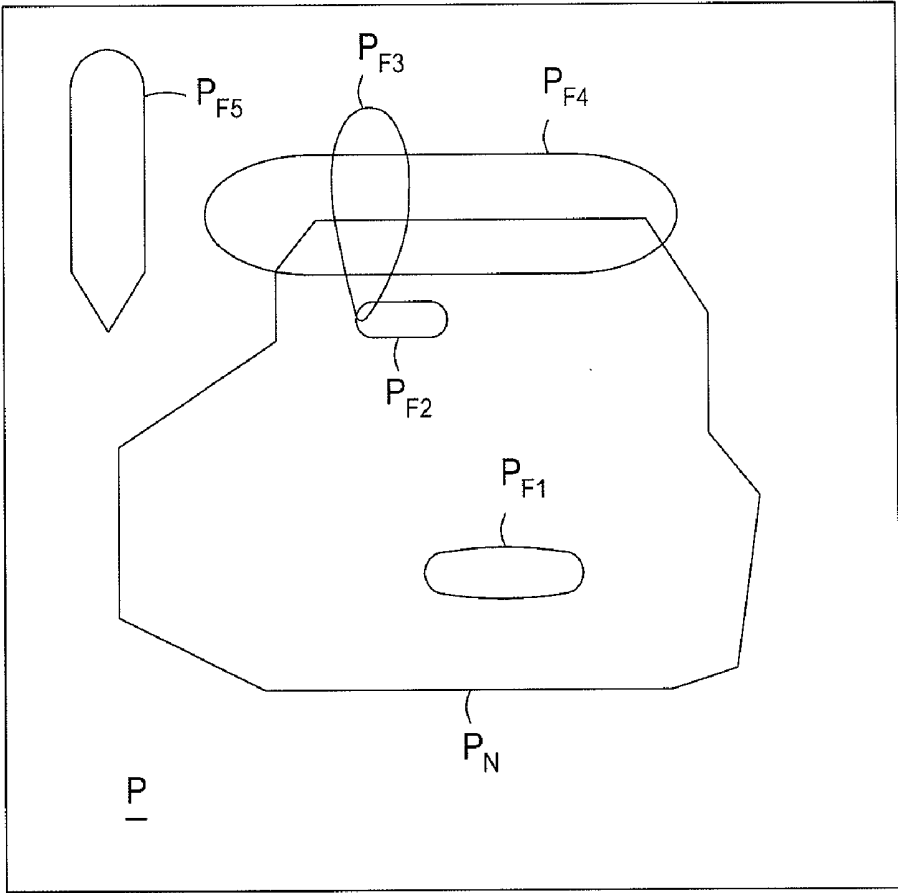


FIG. 4

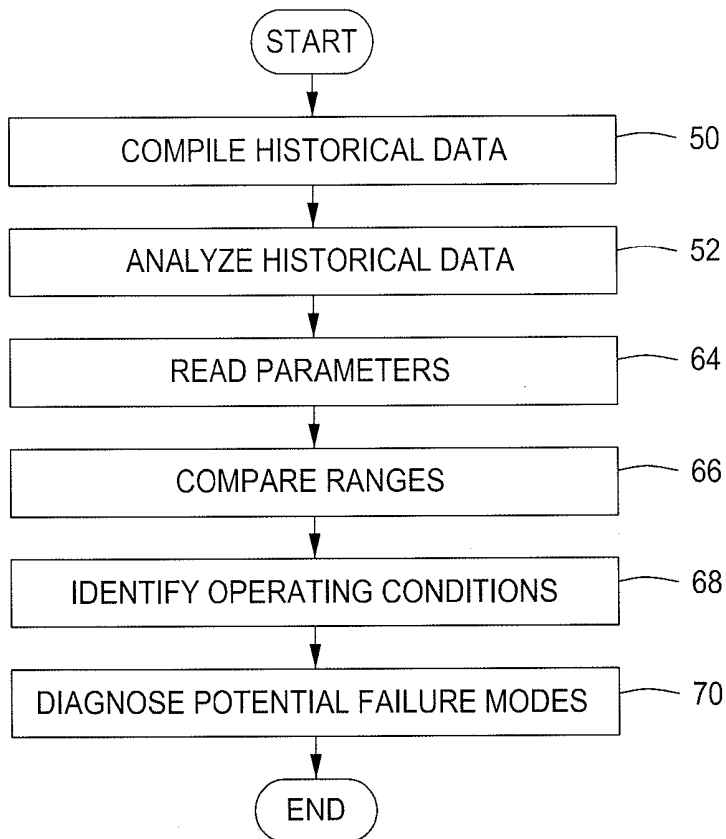


FIG. 5

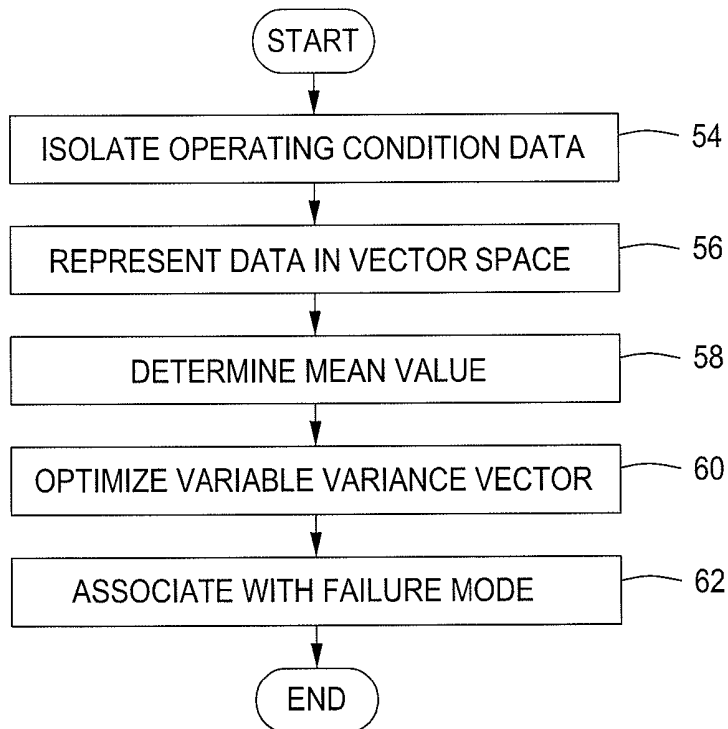


FIG. 6

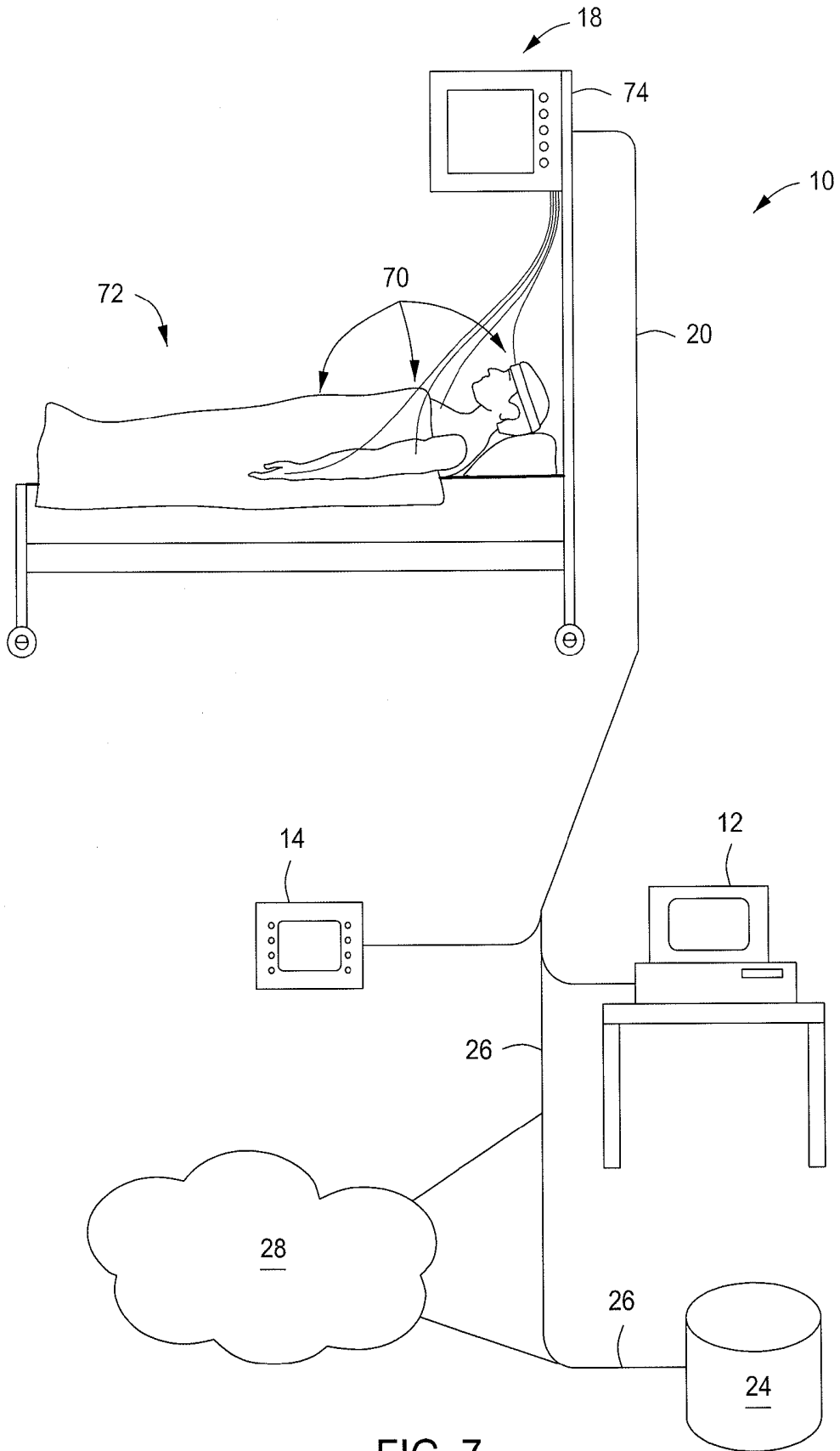


FIG. 7

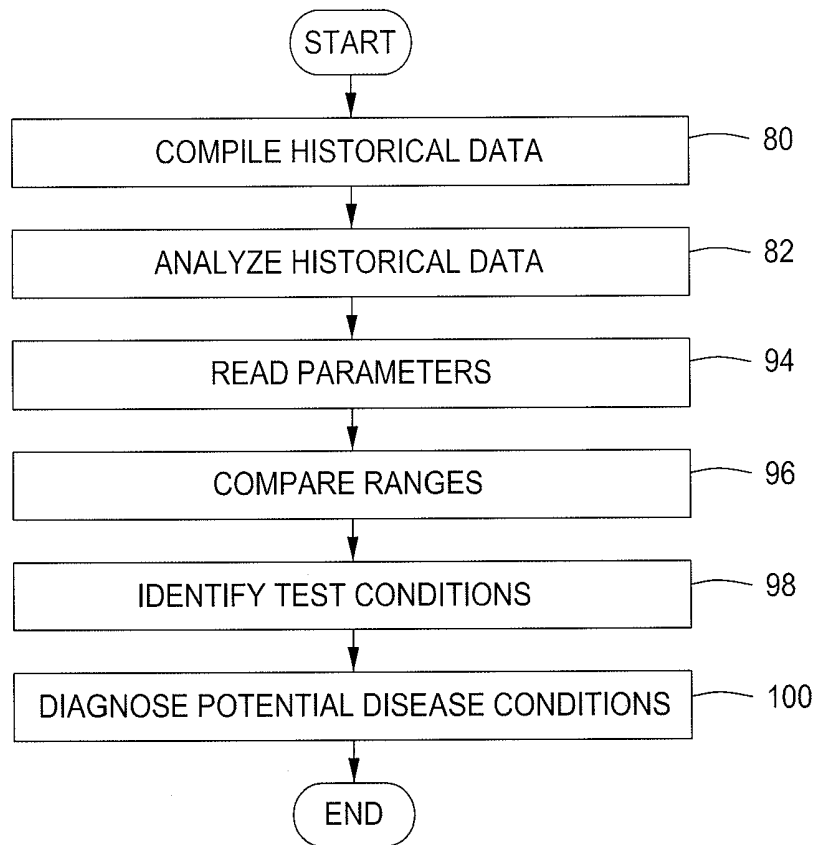


FIG. 8

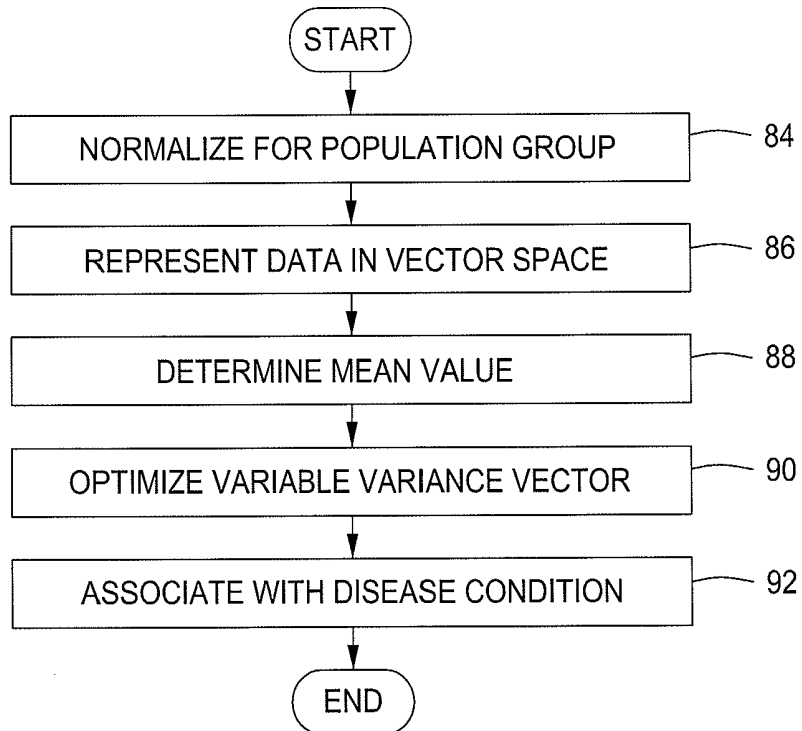


FIG. 9

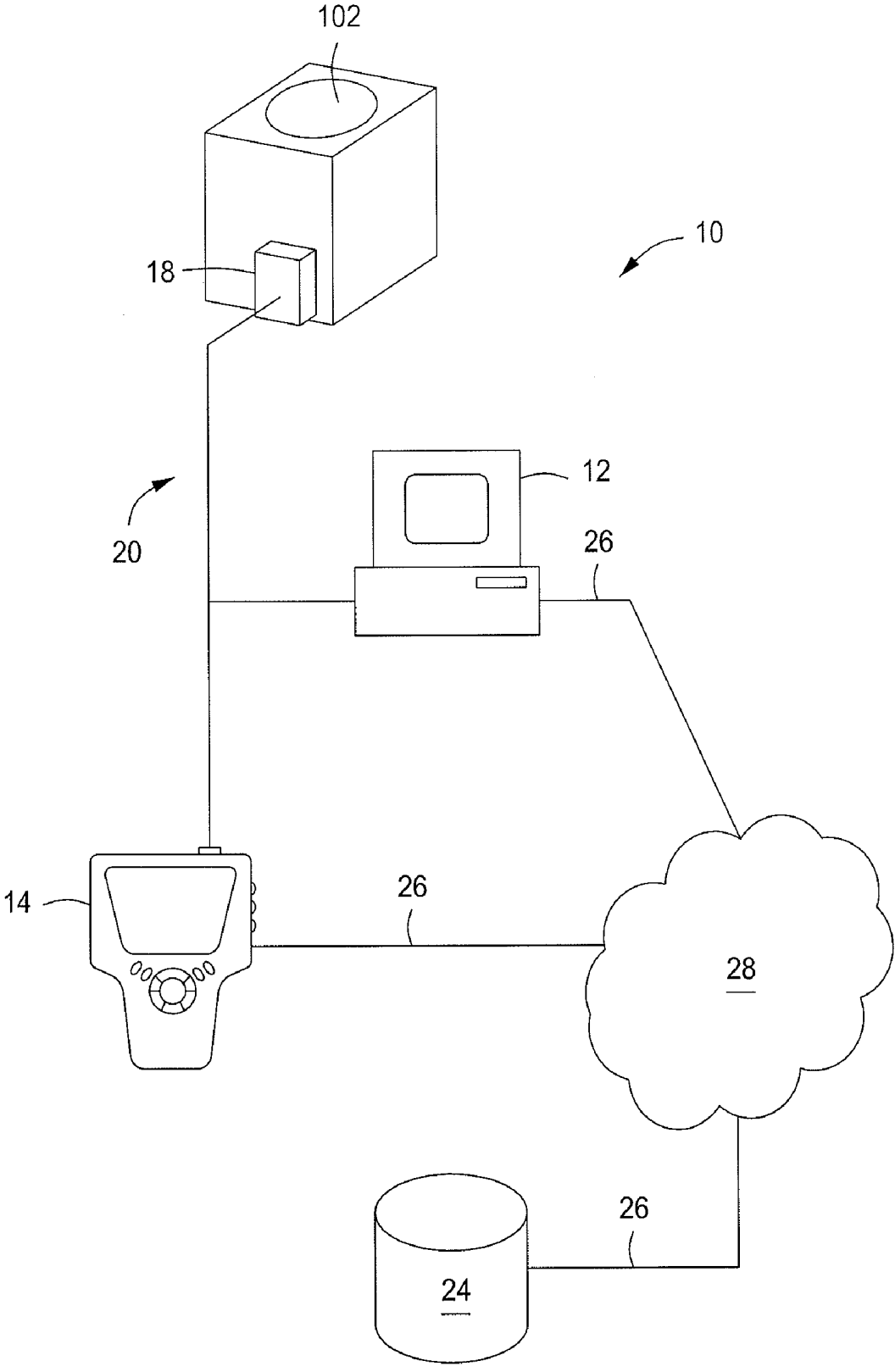


FIG. 10

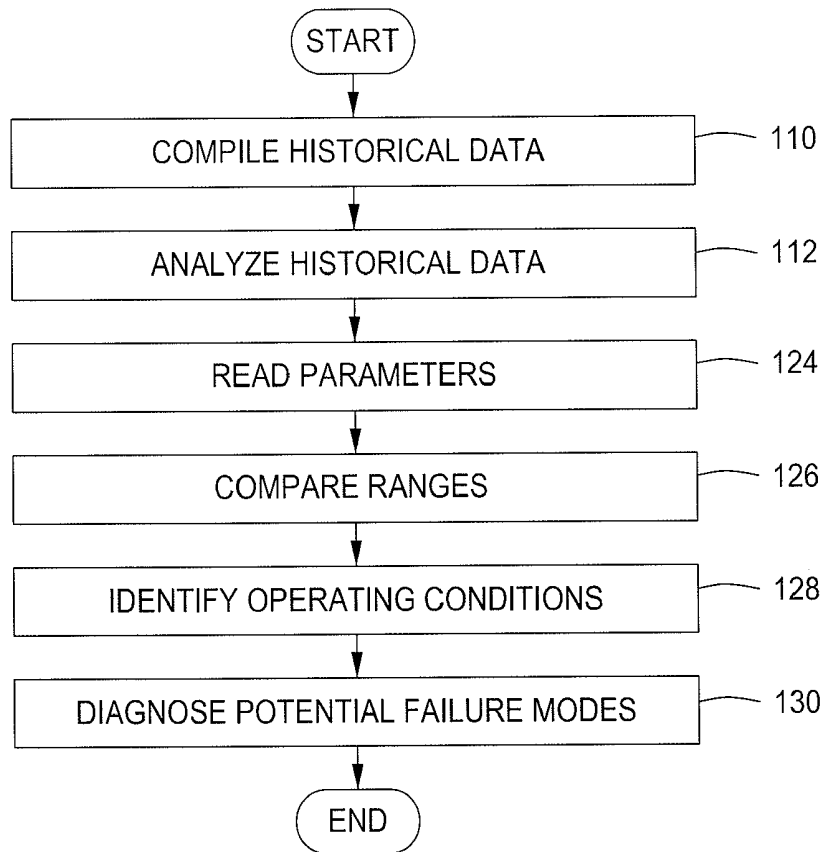


FIG. 11

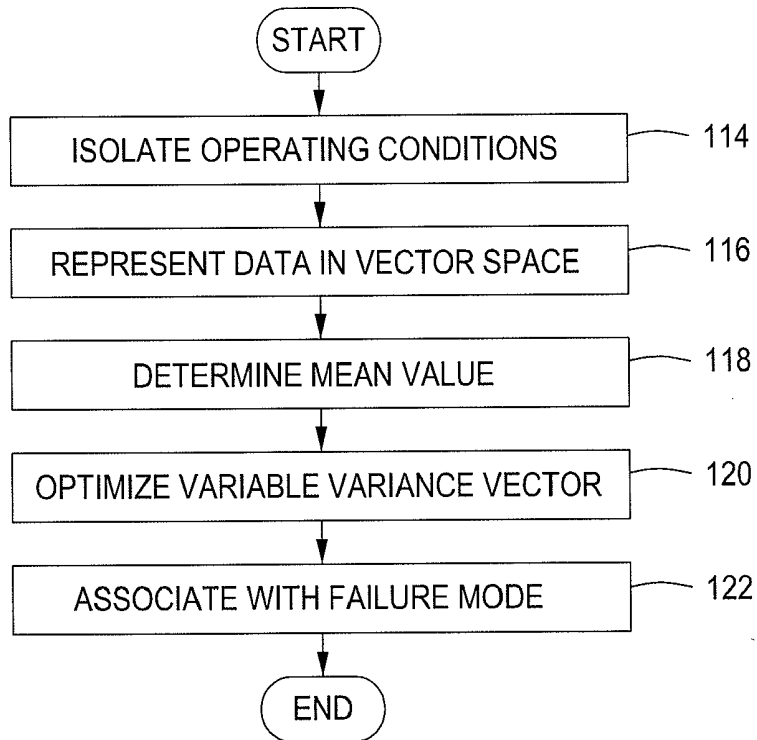


FIG. 12

DIAGNOSTICS DATA COLLECTION AND ANALYSIS METHOD AND APPARATUS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims benefit of and is a continuation-in-part of U.S. patent application Ser. No. 11/478,339, now issued as U.S. Pat. No. 7,751,955, entitled "DIAGNOSTICS DATA COLLECTION AND ANALYSIS METHOD AND APPARATUS TO DIAGNOSE VEHICLE COMPONENT FAILURES," filed Jun. 30, 2006, which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

[0002] The present invention relates generally to diagnostic equipment. More particularly, the present invention relates to the collection and analysis of diagnostics data to diagnose operational or functional problems, such as vehicle component failures.

BACKGROUND OF THE INVENTION

[0003] Diagnostic systems are used by technicians and professionals in virtually all industries to perform basic and advanced system testing functions. For example, in the automotive, trucking, heavy equipment and aircraft industries, diagnostic test systems provide for vehicle onboard computer fault or trouble code display, interactive diagnostics, multiscopes and multimeter functions, and electronic service manuals. In the medical industry, diagnostic systems provide for monitoring body functions and diagnosis of medical conditions, as well as system diagnostics to detect anomalies in the medical equipment.

[0004] In many industries, diagnostic systems play an increasingly important role in manufacturing processes, as well as in maintenance and repair throughout the lifetime of the equipment or product. Some diagnostic systems are based on personal computer technology and feature user-friendly, menu-driven diagnostic applications. These systems assist technicians and professionals at all levels in performing system diagnostics on a real-time basis.

[0005] With the advent of the microprocessor, virtually all modern vehicles have come to utilize onboard computers to control and monitor engine and electrical system functions. Such vehicle onboard computers typically interface with a multiplicity of sensors and transducers, which continuously detect vehicle and engine operational parameters and provide representative electrical signals to the onboard computer. The data collected and processed by the onboard computer can be useful in the diagnosis of vehicle engine and electrical system malfunctions. Thus, the vehicle onboard computer typically includes a communication port connector that allows certain of the collected data to be transmitted to an independent computer analyzer, which may process the data, store the data, or present the data in a visual format that can be interpreted by vehicle maintenance and repair technicians.

[0006] In conjunction with these technological developments, a variety of specialized computer analyzers, or vehicle diagnostic tools, have been developed and marketed to provide vehicle maintenance and repair technicians access to the data available from the vehicle onboard computers. The current technology includes a variety of hand-held vehicle diagnostic tools, frequently referred to as scan tools, with considerable processing capabilities, typically incorporating an

integral display and capable of displaying the onboard computer data in a variety of graphical formats that allow vehicle technicians to view and interpret the data.

[0007] A typical diagnostic system includes a display on which instructions for diagnostic procedures are displayed. The system also includes a system interface that allows the operator to view real-time operational feedback and diagnostic information. Thus, the operator may view, for example, vehicle engine speed in revolutions per minute, or battery voltage during start cranking; or, with regard to the medical field, a patient's heartbeat rate or blood pressure. With such a system, a relatively inexperienced operator may perform advanced diagnostic procedures and diagnose complex operational or medical problems.

[0008] However, if an operator or technician is unable to detect an operational problem and the onboard computer has not detected a fault condition, a potential failure condition may in some cases go unnoticed. Accordingly, it is desirable to provide a method and apparatus that can be executed on diagnostic systems to collect historical operational data corresponding to normal and failure conditions, analyze the data and compare the results of the data analysis to test data gathered from a specific test subject in order to diagnose potential failure conditions that otherwise might be overlooked.

SUMMARY OF THE INVENTION

[0009] The foregoing needs are met, to a great extent, by the present invention, wherein in one aspect an apparatus and method are provided that in some embodiments provide for collecting historical operational data corresponding to normal and disease or failure conditions, analyzing the data and comparing the results of the data analysis to test data gathered from a specific test subject in order to diagnose potential diseases or failure conditions that otherwise might be overlooked.

[0010] An embodiment of the present invention pertains to a computer-implemented method of analyzing medical data. In this method, a collection of historical test data points from a plurality of population types is compiled via a processor of a diagnostic device. Each historical test data point is correlated, via the processor, with a population type to produce entries of a diagnostic case history. The entries of the diagnostic case history are grouped, via the processor, by population type. A range corresponding to the population type of a patient are defined, via the processor, based on the collection of test data points of the entries of the diagnostic case history grouped by population type. A disease condition of the patient is diagnosed, via the processor, based on the range corresponding to the disease condition for the population type.

[0011] Another embodiment of the present invention relates to a computer program product for analyzing vehicle test data to diagnose a failure mode of a vehicle component. This computer program product includes a computer-readable medium encoded with instructions configured to be executed by a processor in order to perform predetermined operations. Based upon these instructions, a collection of historical test data points from a plurality of population types is compiled via a processor of a diagnostic device. Each historical test data point is correlated, via the processor, with a population type to produce entries of a diagnostic case history. The entries of the diagnostic case history are grouped, via the processor, by population type. A range corresponding to the population type of a patient are defined, via the processor, based on the collection of test data points of the entries of

the diagnostic case history grouped by population type. A disease condition of the patient is diagnosed, via the processor, based on the range corresponding to the disease condition for the population type.

[0012] Yet another embodiment of the present invention pertains to a diagnostic tool for analyzing medical data. The diagnostic tool includes a processor and a memory. The processor is configured to execute software modules. The memory is configured to store the software modules, and communicatively connected to the processor. The software modules include a data compiler, a data analyzer, and a virtual diagnostician. The data compiler is configured to compile a collection of historical test data points which includes a plurality of medical measurements corresponding to a plurality of population types. The data analyzer configured to correlate each historical test data point with a disease condition to produce entries of a diagnostic case history, group the entries of the diagnostic case history by population type, and define a range corresponding to the disease condition of a population type based on the collection of test data points of the entries of the diagnostic case history grouped by population type. The virtual diagnostician is configured to diagnose a disease condition in a patient based on the medical data of the patient corresponding to a disease condition in the population type of the patient.

[0013] Yet another embodiment of the present invention relates to a computer-implemented method of analyzing A/C unit test data. In this method, a collection of historical test data points which includes a plurality of operating parameter measurements recorded by an individual A/C unit's onboard computer is compiled, via a processor of a diagnostic device. The diagnostic device and the A/C unit are separate but connectable objects. Each historical test data point is correlated, via the processor, with an operating condition to produce entries of a diagnostic case history. The entries of the diagnostic case history are grouped, via the processor, by operating condition. A range corresponding to the operating condition of a A/C unit type are defined, via the processor, based on the collection of test data points of the entries of the diagnostic case history grouped by operating condition. An A/C unit component failure mode is diagnosed, via the processor, based on the range corresponding to a failure condition. The operating parameters are selected from the group consisting of: a switch position, a motor run condition, a motor speed, a test equipment connection, a A/C unit electrical connection condition, an ambient air temperature, an output air temperature, a refrigerant pressure, and a refrigerant type.

[0014] Yet another embodiment of the present invention pertains to a computer program product for analyzing A/C unit test data. The computer program product includes a computer-readable medium encoded with instructions configured to be executed by a processor in order to perform predetermined operations. Based upon the instructions, a collection of historical test data points which includes a plurality of operating parameter measurements recorded by an individual A/C unit's onboard computer is compiled, via a processor of a diagnostic device. The diagnostic device and the A/C unit are separate but connectable objects. Each historical test data point is correlated, via the processor, with an operating condition to produce entries of a diagnostic case history. The entries of the diagnostic case history are grouped, via the processor, by operating condition. A range corresponding to the operating condition of a A/C unit type are defined, via the processor, based on the collection of test data points of the

entries of the diagnostic case history grouped by operating condition. An A/C unit component failure mode is diagnosed, via the processor, based on the range corresponding to a failure condition. The operating parameters are selected from the group consisting of: a switch position, a motor run condition, a motor speed, a test equipment connection, a A/C unit electrical connection condition, an ambient air temperature, an output air temperature, a refrigerant pressure, and a refrigerant type.

[0015] Yet another embodiment of the present invention relates to a diagnostic tool for analyzing A/C unit test data. The diagnostic tool includes a processor and a memory. The processor is configured to execute software modules. The memory is configured to store the software modules, and communicatively connected to the processor. The software modules include a data compiler, a data analyzer, and a virtual diagnostician. The data compiler is configured to compile a collection of historical test data points which includes a plurality of operating parameter measurements recorded by an individual A/C unit's onboard computer. The diagnostic tool and the A/C unit are separate but connectable objects. The data analyzer is configured to correlate each historical test data point with an operating condition to produce entries of a diagnostic case history, group the entries of the diagnostic case history by operating condition, and define a range corresponding to the operating condition of a A/C unit type based on the collection of test data points of the entries of the diagnostic case history grouped by operating condition. The virtual diagnostician is configured to diagnose a A/C unit component failure mode based on the range corresponding to a failure condition. The operating parameters are selected from the group consisting of: a switch position, a motor run condition, a motor speed, a test equipment connection, a A/C unit electrical connection condition, an ambient air temperature, an output air temperature, a refrigerant pressure, and a refrigerant type.

[0016] There has thus been outlined, rather broadly, certain embodiments of the invention in order that the detailed description thereof herein may be better understood, and in order that the present contribution to the art may be better appreciated. There are, of course, additional embodiments of the invention that will be described below and which will form the subject matter of the claims appended hereto.

[0017] In this respect, before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and to the arrangements of the components set forth in the following description or illustrated in the drawings. The invention is capable of embodiments in addition to those described and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein, as well as the abstract, are for the purpose of description and should not be regarded as limiting.

[0018] As such, those skilled in the art will appreciate that the conception upon which this disclosure is based may readily be utilized as a basis for the designing of other structures, methods and systems for carrying out the several purposes of the present invention. It is important, therefore, that the claims be regarded as including such equivalent constructions insofar as they do not depart from the spirit and scope of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] FIG. 1 illustrates a representative vehicle diagnostic data collector/analyzer according to an embodiment of the invention.

[0020] FIG. 2 is a schematic diagram illustrating the vehicle diagnostic data collector/analyzer.

[0021] FIG. 3 illustrates a representative tree graph representation of a data structure that can be implemented by the vehicle diagnostic data collector/analyzer.

[0022] FIG. 4 is a diagrammatic representation illustrating a 2-dimensional parameter state space.

[0023] FIG. 5 is a flowchart illustrating steps that may be followed in accordance with one embodiment of the method or process of collecting and analyzing diagnostic data to diagnose potential failure conditions in a vehicle.

[0024] FIG. 6 is a flowchart illustrating steps that may be followed in accordance with the method or process of collecting and analyzing diagnostic data in order to analyze historical vehicle diagnostic data.

[0025] FIG. 7 illustrates a representative diagnostic data collector/analyzer according to another embodiment of the invention.

[0026] FIG. 8 is a flowchart illustrating method steps that may be followed in accordance with the embodiment of FIG. 7 for collecting and analyzing diagnostic data to diagnose medical conditions in a patient.

[0027] FIG. 9 is a flowchart illustrating method steps that may be followed in accordance with the embodiment of FIG. 7 for collecting and analyzing diagnostic data in order to analyze historical medical diagnostic data.

[0028] FIG. 10 illustrates a representative diagnostic data collector/analyzer according to yet another embodiment of the invention.

[0029] FIG. 11 is a flowchart illustrating method steps that may be followed in accordance with the embodiment of FIG. 10 for collecting and analyzing diagnostic data to diagnose conditions in an A/C unit.

[0030] FIG. 12 is a flowchart illustrating method steps that may be followed in accordance with the embodiment of FIG. 10 for collecting and analyzing diagnostic data in order to analyze historical diagnostic data.

DETAILED DESCRIPTION

[0031] A representative embodiment in accordance with the present invention provides a vehicle diagnostic data collector/analyzer that can collect historical vehicle operational data corresponding to various normal vehicle operating conditions and vehicle component failure conditions, analyze the data and compare the results of the data analysis to test data gathered from a specific test-subject vehicle in order to diagnose potential failure conditions of vehicle components. The vehicle diagnostic data collector/analyzer can be useful in diagnosing failure conditions that otherwise might be overlooked.

[0032] For example, an operator or technician may in some cases be unable to directly detect a potential failure condition based on a vehicle onboard computer trouble code or codes, or a vehicle operational symptom or symptoms, even though a potential failure condition exists. Nonetheless, in such a case the vehicle diagnostic data collector/analyzer may be able to monitor test-subject vehicle operational parameters and diagnose a potential vehicle component failure mode by way of a comparison between the test-subject vehicle data and analyzed data previously collected from other vehicles, including data collected from other vehicles of the same type as the test-subject vehicle having a known failure condition.

[0033] Alternative embodiments in accordance with the present invention can provide a diagnostic data collector/

analyzer for use in a field other than vehicle diagnostics. For example, an alternative embodiment can provide a medical diagnostic data collector/analyzer for use by medical professionals or technicians that can collect historical medical data corresponding to various normal bodily functions and abnormal bodily functions, analyze the data and compare the results of the data analysis to test data gathered from a specific patient in order to diagnose potential abnormalities in the patient. Similarly, additional alternative embodiments can provide a diagnostic data collector/analyzer for use in other fields, such as the pharmaceutical industry, the chemical industry, the petroleum industry, or the like.

[0034] The representative vehicle diagnostic data collector/analyzer can include a data compiler to gather and compile historical diagnostic data, including measured operating parameters from a number of different vehicles operating under a variety of normal conditions or failure conditions. The diagnostic data collector/analyzer can also include a data analyzer to analyze the historical diagnostic data. For example, the data analyzer can isolate and categorize data corresponding to parameters measured on a number of individual vehicle types under a variety of particular operating conditions and perform statistical analysis on the various vehicle type/operating condition combinations to define operating parameter ranges corresponding to normal operating conditions and a variety of failure conditions.

[0035] In addition, the vehicle diagnostic data collector/analyzer can include a parameter reader to measure real-time operating parameters on a specific test-subject vehicle, and a comparator to evaluate differences and similarities between the operating parameter measurements and established ranges corresponding to normal operating conditions and failure conditions. Furthermore, the diagnostic data collector/analyzer can include a condition identifier to correlate the operating parameter measurement with known operating conditions, and a virtual diagnostician to diagnose specific potential vehicle component failure modes based on the operating parameter measurements. The invention will now be described with reference to the drawing figures, in which like reference numerals refer to like parts throughout.

[0036] FIG. 1 illustrates a representative vehicle diagnostic data collector/analyzer 10 that can aid a vehicle technician in identifying potential vehicle failure modes at the component level. An embodiment of the vehicle diagnostic data collector/analyzer 10 can include a personal computer (PC) 12 or a hand-held diagnostic scan tool 14 configured to be coupled to a vehicle 16. The vehicle 16 can include an onboard computer 18 that can be accessed by way of electrical links 20, such as such as conductors, wires, cables, data buses, a communication network or a wireless network, and optionally a vehicle interface box 22 to provide signal conditioning.

[0037] The vehicle diagnostic data collector/analyzer 10 can further include a database 24 coupled to the personal computer 12 or scan tool 14, for example, by way of local links 26 and a communication network 28. In an alternative embodiment, the database 24 can be stored directed in a memory associated with the personal computer 12 or the scan tool 14.

[0038] FIG. 2 is a schematic diagram illustrating the vehicle diagnostic data collector/analyzer 10, which can include a processor 30, a memory 32, an input/output device 34, a data compiler 36, a data analyzer 38, a parameter reader 40, a comparator 42, a condition identifier 44, and a virtual diagnostician 46, all of which can be coupled by a data link

48. The vehicle diagnostic data collector/analyzer **10** can collect historical vehicle operational data corresponding to various normal vehicle operating conditions and vehicle component failure conditions, analyze the data and compare the results of the data analysis to test data gathered from a specific test-subject vehicle in order to diagnose potential failure conditions of vehicle components.

[0039] The processor **30**, the memory **32**, and the input/output (I/O) device **34** can be part of a general computing device, such as a personal computer (PC), a notebook, a UNIX workstation, a server, a mainframe computer, a personal digital assistant (PDA), a mobile telephone, or some combination of these. Alternatively, the processor **30**, the memory **32** and the input/output device **34** can be part of a specialized computing device, such as a vehicle diagnostics scan tool **14**. The remaining components can include programming code, such as source code, object code or executable code, stored on a computer-readable medium that can be loaded into the memory **32** and processed by the processor **30** in order to perform the desired functions of the vehicle diagnostic data collector/analyzer **10**.

[0040] In various embodiments, the vehicle diagnostic data collector/analyzer **10** can be coupled to a communication network **28**, which can include any viable combination of devices and systems capable of linking computer-based systems, such as the Internet; an intranet or extranet; a local area network (LAN); a wide area network (WAN); a direct cable connection; a private network; a public network; an Ethernet-based system; a token ring; a value-added network; a telephony-based system, including, for example, T1 or E1 devices; an Asynchronous Transfer Mode (ATM) network; a wired system; a wireless system; an optical system; a combination of any number of distributed processing networks or systems or the like.

[0041] An embodiment of the vehicle diagnostic data collector/analyzer **10** can be coupled to the communication network **28** by way of local data link **26**, which in various embodiments can incorporate any combination of devices—as well as any associated software or firmware—configured to couple processor-based systems, such as modems, network interface cards, serial buses, parallel buses, LAN or WAN interfaces, wireless or optical interfaces and the like, along with any associated transmission protocols, as may be desired or required by the design.

[0042] An embodiment of the vehicle diagnostic data collector/analyzer **10** can communicate information to the user and request user input by way of an interactive, menu-driven, visual display-based user interface, or graphical user interface (GUI). The user interface can be executed, for example, on a personal computer (PC) with a mouse and keyboard, with which the user may interactively input information using direct manipulation of the GUI displayed, for example, on a PC monitor, or another input/output device **34**, such as a microphone. Direct manipulation can include the use of a pointing device, such as a mouse or a stylus, to select from a variety of selectable fields, including selectable menus, drop-down menus, tabs, buttons, bullets, checkboxes, text boxes, and the like. Nevertheless, various embodiments of the invention may incorporate any number of additional functional user interface schemes in place of this interface scheme, with or without the use of a mouse or buttons or keys, including for example, a trackball, a touch screen or a voice-activated system.

[0043] The vehicle diagnostic data collector/analyzer **10** can define or utilize a predefined component taxonomy corresponding to the vehicle, for example, in the form of a connected acyclic directed graph, such as that shown in FIG. **3**. Thus, viewing the graph of FIG. **3** as an abstraction of a component taxonomy, each node of the graph can represent a component, CT_n , of the vehicle. For example, the root node **N1** can represent the vehicle as a single unit. Each node connected to the root node **N1** can represent a major component of the vehicle. For example, node **N11** can represent an engine, and node **N12** can represent a transmission. Likewise, each of the connected “sibling” nodes can represent an individual subcomponent. For example, node **N111** can represent a fuel control unit, and node **N112** can represent an oxygen sensor, and so on.

[0044] In association with the component taxonomy, the diagnostic data collector/analyzer **10** can also define or utilize a predefined fault taxonomy, by associating one or more failure modes with each component node, $FM_n^* = \{FM_{n1}, \dots, FM_{nm}\}$. For example, each associated failure mode can describe a specific modality of failure for the component, and the set of failure modes associated with a particular component, FM_n^* , can represent all known ways the particular component can fail.

[0045] In addition, the diagnostic data collector/analyzer **10** can define or utilize a predefined diagnostic taxonomy by associating at least one failure mode test, FMT_{xy} , with each failure mode, FM_{xy} , which can be interpreted as an elementary diagnostic procedure intended to prove or disprove (conclusively or inconclusively) a hypothesis regarding the presence of a particular failure mode. Furthermore, the diagnostic data collector/analyzer **10** can define a repair taxonomy by associating at least one repair procedure with each failure mode.

[0046] Returning to FIG. **2**, the data compiler **36** can gather and organize historical vehicle diagnostic data samples corresponding to various normal vehicle operating conditions and vehicle component failure conditions. Thus, the historical diagnostic data can include various measured operating parameters from a number of different vehicles operating under a variety of normal conditions or failure conditions. Historical data can be collected as a “snapshot”—a single set of measurements at a moment in time—or as a “data strip”—a sequence or series of periodic measurements taken over a period of time. For example, the data compiler can collect historical operating parameter data including, for example, the following:

- [0047]** an ignition switch position
- [0048]** an engine run condition
- [0049]** a throttle position
- [0050]** an engine speed
- [0051]** a vehicle speed
- [0052]** a test equipment connection
- [0053]** a vehicle electrical connection condition
- [0054]** an ambient air temperature
- [0055]** an engine inlet temperature
- [0056]** an engine lubricant pressure
- [0057]** an engine lubricant temperature
- [0058]** an engine lubricant level
- [0059]** an engine coolant temperature
- [0060]** an engine coolant specific gravity
- [0061]** an engine exhaust gas temperature
- [0062]** an engine exhaust gas content
- [0063]** a transmission setting

- [0064] a brake pedal position
- [0065] a parking brake position
- [0066] a brake fluid pressure
- [0067] a fuel level
- [0068] a fuel supply pressure
- [0069] a battery voltage
- [0070] a battery charging system voltage
- [0071] a battery charging system current
- [0072] an ignition voltage
- [0073] an ignition current
- [0074] an engine cylinder compression

[0075] The data compiler **36** can create a database **24** in which to accumulate the historical data, for example, a relational database that associates each instance of measured parameters with a definition or description of the prevailing ambient and operating conditions under which the data were gathered. For example, the database **24** can associate the historical data with a vehicle manufacturer, make and model, as well as ambient conditions during which the data were recorded, fault codes previously or simultaneously recorded by the vehicle onboard computer **18**, operational problems or symptoms observed in association with the recording of the data, and any known failure conditions present during the recording of the data.

[0076] In some embodiments of the vehicle diagnostic data collector/analyzer **10** this information can be recorded automatically, for example, by the personal computer **12** or by the scan tool **14**. For example, a scan tool **14**, including existing scan tools, can be programmed to automatically collect vehicle operating parameters each time the scan tool **14** is connected to a vehicle. In other embodiments, a scan tool **14** can be programmed to record vehicle operating parameters when explicitly requested, for example, in response to a user input by way of an input/output device **34**.

[0077] In still other embodiments, the condition factors or historical data information can be entered by a user, for example, by way of direct manipulation of a menu listing possible conditions. Furthermore, the vehicle diagnostic data can be collected by way of the vehicle onboard computer **18**, for example, recording data items that are monitored by the onboard computer **18**, such as engine speed, engine coolant temperature, and the like. The data signals can optionally be subjected to signal conditioning, for example, by the vehicle interface box **22**. Moreover, the vehicle diagnostic data can be collected by way of another monitoring device, such as an analog or digital multimeter.

[0078] Thus, historical data collection can be implemented by a vehicle diagnostic system. Examples of compatible PC-based vehicle diagnostic methods and systems are disclosed in U.S. Pat. No. 5,631,831, entitled "Diagnosis Method for Vehicle Systems," to Bird, et al., dated May 20, 1997, and in copending U.S. patent application Ser. No. 11/452,249, entitled "Dynamic Decision Sequencing Method and Apparatus," filed Jun. 14, 2006 by Fountain, et al., the disclosures of which are hereby incorporated by reference in their entirety.

[0079] An example of a suitable vehicle diagnostics scan tool **14** compatible with an embodiment of the present invention is the Genisys™ scan tool, manufactured by the OTC Division of the SPX Corporation in Owatonna, Minn. A variety of features of the Genisys™ system are disclosed in U.S. patents, such as U.S. Pat. No. 6,236,917; U.S. Pat. No. 6,538,472; U.S. Pat. No. 6,640,166; U.S. Pat. No. 6,662,087; and

U.S. Pat. No. 6,874,680; the disclosures of which are incorporated herein by reference in their entirety.

[0080] However, other embodiments are compatible with additional vehicle diagnostic tools, including any number of commercially available makes and models, such as the SUPER AutoScanner and the EZ 3/4/5/6000 Scan Tools, also manufactured by the SPX Corporation; the StarSCAN scan tool, manufactured for DaimlerChrysler Corporation by SPX; or the Snap-on Scanner, MicroSCAN, MODIS, or SOLUS series, manufactured by Snap-on Technologies, Inc.; or any other device capable of receiving and processing vehicle diagnostic data from a vehicle onboard computer, such as a personal computer (PC) or a personal digital assistant (PDA).

[0081] Furthermore, in some embodiments of the vehicle diagnostic data collector/analyzer **10**, the data compiler **36** can automatically, or optionally, upon manual request, send the historical data to central repository, such as a remote database **24**, for example, over a communication network **28**, such as a local area network (LAN), an intranet or the Internet. Thus, historical data from numerous distinct sites, such as repair centers around a nation or around the world, can be transmitted to a central databank for storage or analysis. The data can be further associated or categorized within the database **24** according to various factors, including site of origin, ambient condition, failure condition, and the like. Thus, examples of historical data categories could include the following:

[0082] Mercury Cougar XL, 2.5 L V6, automatic transmission, 20-30,000 miles, warmed-up idle, no fault code, Seattle, Wash., 70-74° F.

[0083] Pontiac Solstice, 2.4 L 4-cyl., 5-speed manual transmission, factory new, 3200 rpm, fault code **342**, Detroit, Mich., 55-59° F.

[0084] Toyota RAV4, 2.0 L 4-cyl., 5-speed manual transmission, 4WD, 40-50,000 miles, warmed-up idle, high CO emission, Washington, D.C., 95-99° F.

[0085] Volvo V70, 2.5 L 5-cyl. Turbo, automatic transmission, 0-10,000 miles, starter crank, cranks but does not start, Göteborg, Sweden, 20-24° F.

[0086] The data analyzer **38** can analyze historical data samples to determine typical ranges for operating parameter measurements corresponding to various normal and failure conditions. For example, the data analyzer **38** can isolate data samples corresponding to parameters measured on an individual vehicle type under a particular operating condition or failure condition, and perform statistical analyses on the data samples to define operating parameter ranges corresponding to the particular operating condition or failure condition. Various levels of parameter ranges can be established, for example, "ideal," "OK-lower-limit," "OK-upper-limit," "warning," "danger," etc.

[0087] The statistical analyses can include calculating, for example, a minimum value, a maximum value, a mean value and a variance or standard deviation for a group of snapshot data sets, an individual data strip, or a set of data strips. In addition, the statistical analyses can identify and eliminate outliers, or data samples that are significantly outside an expected range. Furthermore, a relationship between data sets or between a group of data strips can be expressed as a correlation data strip, for example, having minimum, maximum and mean values, variance, standard deviation, and periodicity that can be statistically evaluated.

[0088] Furthermore, data strips, including multiple simultaneous data strips, can be evaluated using linear transforms, such as the Fourier transform. For example, the data strips can be decomposed into discrete units, such as sinusoids of varying frequency and amplitude, that correspond to known conditions or subconditions that can be identified in the database **24**.

[0089] In some embodiments of the vehicle diagnostic data collector/analyzer **10**, the data analyzer **38** can define a diagnostic case history, "DC*," as an ordered list of diagnostic cases, that is historical data samples, "p," corresponding to a particular diagnosis, or failure condition, for example:

$$DC = \begin{cases} \langle p_{11}, \text{diagnosis}_{\langle 1,1 \rangle} \rangle, \\ \langle p_{12}, \text{diagnosis}_{\langle 1,2 \rangle} \rangle, \\ \vdots \\ \langle p_{n,m}, \text{diagnosis}_{\langle n,m \rangle} \rangle \end{cases}$$

Thus, the diagnosis can correspond to an end-node, or leaf, in the diagnostic taxonomy.

[0090] Furthermore, in some embodiments of the vehicle diagnostic data collector/analyzer **10**, the historical data samples, "p," can be represented as a point in a multidimensional vector space having dimensionality equal to the number of measured parameters, "k." Thus, for a particular vehicle type, "V," the data analyzer **38** can define a parameter state space, "P," as a "k"-dimensional Euclidean space representing the value range of all "k" measured parameter values in a set of historical data samples. Thus, in general, each historical data sample, "p," is represented by a single point in the parameter state space, "P."

[0091] The data analyzer **38** can further define a normal range, or nominal range, in "P" for each parameter, "p," that corresponds to the historical data samples representing a normal operating condition free of vehicle component failures, that is, data samples taken from vehicles known to be well-functioning and not exhibiting symptoms, such as observed operational problems or fault codes set by the onboard computer **18**. Thus, the data analyzer **38** can associate with the vehicle type, "V," a "k"-dimensional subset of "P," designated "P^{Normal}," embedded within the surface of a manifold, "M^{Normal}," having dimensionality "k-1".

[0092] In a similar fashion, the data analyzer **38** can define multiple subsets of "P," collectively "P^{Abnormal}," including parameter state spaces corresponding to historical data samples from vehicles operating under a diagnosed failure condition, {P^{Failure}_{<1,1>}, . . . , P^{Failure}_{<n,m>}}. Thus, the failure condition operating parameter spaces, {P^{Failure}_{<1,1>}, . . . , P^{Failure}_{<n,m>}}, can be derived from the diagnostic case histories, "DC*." Each member, "P^{Failure}_{<p,q>}," of the set, "P^{Abnormal}," can represent the parameter state space of expected parameter values corresponding to a manifestation of a particular failure mode, "FM^p_q," which indicates the presence of a specific failure modality of a vehicle component, CT_p.

[0093] FIG. 4 is a diagrammatic representation of a 2-dimensional parameter state space P, which for purposes of demonstration can be viewed as an abstraction of a higher-dimensional parameter space. The abstract representation of FIG. 4 can be expanded to any dimensionality, representing any number of measured parameters. Within the parameter state space P, are various parameter spaces representing different operating conditions corresponding to a vehicle type.

For example, the normal operating condition parameter space P_N represents a parameter space corresponding to normal vehicle operation without any component failures present. The additional parameter spaces P_{F1}, P_{F2}, P_{F3}, P_{F4} and P_{F5} correspond to failure operating conditions of the vehicle where some vehicle component failure is present.

[0094] The areas of P where two or more of the parameter spaces overlap represent parameter spaces wherein one of the operating conditions may exist, or wherein more than one operating condition may coexist. For example, within the area representing the intersection of P_N, P_{F2} and P_{F3}, the vehicle may be operating normally; or either a failure condition corresponding to P_{F2} may exist, or a failure condition corresponding to P_{F3}, may exist; or a dual failure condition corresponding to both P_{F2} and P_{F3} may exist. Regarding the areas where two or more of the parameter spaces overlap, statistical analyses known in the art, such as a method of Bayesian analysis, can be implemented to provide a probabilistic estimate of the likelihood of the existence of any one of the corresponding operating conditions or failure modes.

[0095] On the other hand, areas of P where only one parameter space is present represent parameter spaces wherein a specific condition conclusively exists. For example, within the area of parameter space P_{F5}, a specific component failure modality can be conclusively inferred from the operating condition, since parameter space P_{F5} is uniquely associated with a specific component failure, and the vehicle can be identified as requiring a repair procedure.

[0096] Returning once again to FIG. 2, based on the normal operating parameter space, "P^{Normal}," and the various failure condition parameter spaces, {P^{Failure}_{<1,1>}, . . . , P^{Failure}_{<n,m>}}, combined with the diagnostic case histories, "DC*," the data analyzer **38** can further define a diagnostic parameter categorization, "PC," as a list of 2-tuplets associating each specific failure mode with a corresponding failure condition parameter space, for example:

$$PC = \begin{cases} \langle \text{No_Fault}, P^{\text{Normal}} \rangle, \\ \langle FM_{11}, P^{\text{Failure}}_{\langle 1,1 \rangle} \rangle, \\ \langle FM_{12}, P^{\text{Failure}}_{\langle 1,2 \rangle} \rangle, \\ \vdots \\ \langle FM_{nm}, P^{\text{Failure}}_{\langle n,m \rangle} \rangle \end{cases}$$

[0097] In the case that any portion of the parameter state space P (see FIG. 4) is not a member of the union of the normal operating parameter space P^{Normal} and the abnormal operating parameter space, "P^{Abnormal}," (P_{F1}, P_{F2}, P_{F3}, P_{F4} and P_{F5} in the example of FIG. 4), then the parameter categorization, "PC," can be said to be 'incomplete.' On the other hand, if the parameter state space P is equal to the union of the normal operating parameter space P^{Normal} and the abnormal operating parameter space, "P^{Abnormal}," then the parameter categorization, "PC," can be said to be 'complete.'

[0098] In some embodiments of the vehicle diagnostic data collector/analyzer **10**, the data analyzer **38** can derive the failure condition operating parameter spaces, {P^{Failure}_{<1,1>}, . . . , P^{Failure}_{<n,m>}}, as well as the parameter categorization, "PC," from the diagnostic case history, "DC*," utilizing methods of automated reasoning that are known in the art. For example, the data analyzer **38** can implement a method of automated reasoning from the field of manifold learning,

including linear methods such as principal component analysis, multi-dimensional scaling, or the like, as well as non-linear methods such as local linear embedding, ISOMAP, Laplacian eigenmap, or the like, in order to create for each set of cases relating to a failure modality of a specific component, an optimized “k-1”-dimensional manifold, which will define, by enclosure, the corresponding set $P^{Failure}_{\langle a, x \rangle}$.

[0099] In an alternative embodiment of the vehicle diagnostic data collector/analyzer 10, the data analyzer 38 can derive the failure condition operating parameter spaces, $\{P^{Failure}_{\langle 1, 1 \rangle}, \dots, P^{Failure}_{\langle n, m \rangle}\}$, as well as the parameter categorization, “PC,” from the diagnostic case history, “DC*,” utilizing methods from the field of neural networks that are known in the art. In yet another alternative embodiment, the data analyzer 38 can derive the failure condition operating parameter spaces, $\{P^{Failure}_{\langle 1, 2 \rangle}, \dots, P^{Failure}_{\langle n, m \rangle}\}$, as well as the parameter categorization, “PC,” from the diagnostic case histories, “DC*,” utilizing genetic algorithms that are known in the art.

[0100] Furthermore, in some embodiments, the data analyzer 38 can construct a variable probabilistic parameter categorization by associating with each failure mode, “ FM^p_q ,” a “k”-dimensional probability distribution, selected from such distributions known in the art, characterized by a mean value and a “k”-dimensional variable variance vector. The data analyzer 38 can further optimize the probabilistic parameter categorization, using methods that are known in the art, for example a method from the field of optimization theory. Thus, the data analyzer 38 can identify an optimal variance vector to fit the diagnostic case history, “DC*.”

[0101] In a yet other embodiments, as a generalization of above, the data analyzer 38 can construct a variable probabilistic parameter categorization by associating with each failure mode, “ FM^p_q ,” a “k”-dimensional probability density function, characterized by a parameterization vector. The data analyzer 38 can further optimize the probabilistic parameter categorization, using methods that are known in the art, for example, a method from the field of optimization theory. Thus, the data analyzer 38 can identify an optimal parameterization vector to fit the diagnostic case history, “DC*.”

[0102] Moreover, in some embodiments of the vehicle diagnostic data collector/analyzer 10, the data analyzer 38 can perform a dimensionality reduction algorithm on the diagnostic case history, “DC*,” or on the parameter categorization, “PC.” The dimensionality reduction algorithm can be selected from those known in the art, including trivial, linear or non-linear dimensionality reduction algorithms. For example, performing a trivial dimensionality reduction on the diagnostic case history, “DC*,” could have the advantage of removing from consideration parameters that have no significant diagnostic impact.

[0103] The parameter reader 40 can record real-time measurements of operating parameters on a specific test-subject vehicle selected for diagnosis. For example, in some embodiments of the vehicle diagnostic data collector/analyzer 10, operating parameters can be recorded by the personal computer 12 or by the scan tool 14. The parameter reader 40 can record the measurements of operating parameters as a “snapshot”—a single set of measurements at a moment in time—or as a “data strip”—a sequence or series of periodic measurements taken over a period of time.

[0104] In addition, in some embodiments of the vehicle diagnostic data collector/analyzer 10, the parameter reader 40 can incorporate test instructions that can be displayed or

presented aurally to instruct a vehicle technician to perform certain functions while the operating parameters are recorded, such as “start vehicle,” “idle engine for 2 minutes,” “maintain 3,000 rpm for 30 seconds,” or the like. In other embodiments, operating parameters can be entered by a user, for example, by way of a keyboard or other entry keys.

[0105] Furthermore, parameter reader 40 can receive the operating parameters by way of the vehicle onboard computer 18, for example, recording data items that are monitored by the onboard computer 18, such as engine speed, engine coolant temperature, and the like. Additionally, the parameter reader 40 can optionally receive the operating parameter signals by way of a signal conditioner, for example, the vehicle interface box 22 shown in FIG. 1. Moreover, parameter reader 40 can record the operating parameters by way of another monitoring device, such as an analog or digital multimeter.

[0106] The comparator 42 can evaluate similarities and differences between the operating parameter measurements recorded by the parameter reader 40 from the test-subject vehicle and the established ranges corresponding to normal operating conditions and failure conditions, including multiple ranges represented by a multidimensional manifold.

[0107] Based on the results from the comparator 42, the condition identifier 44 can correlate the operating parameter measurements from the test-subject vehicle with known operating conditions, including normal operating conditions and failure conditions. The condition identifier 44 can thus identify a known operating condition that corresponds to the operating parameter measurements from the test-subject vehicle, for example, a failure condition corresponding to a failure condition operating parameter space, “ $P^{Failure}_{\langle p, q \rangle}$,” from the set, “ $P^{Abnormal}$,” or a normal operating condition corresponding to the normal operating parameter space, “ P^{Normal} .”

[0108] Additionally, the virtual diagnostician 46, can diagnose specific potential vehicle component failure modes that may be present in the test-subject vehicle based on the operating parameter measurements corresponding to a known failure mode in the diagnostic parameter categorization, “PC,” such as a failure mode corresponding to a failure condition operating parameter space, “ $P^{Failure}_{\langle p, q \rangle}$,” from the set, “ $P^{Abnormal}$.”

[0109] For example, given the test-subject vehicle type, along with the corresponding component taxonomy, CT, diagnostic taxonomy, DT, and diagnostic case history, DC*, based on the parameter categorization, PC, the virtual diagnostician 46 can implement deductive logic to infer either a conclusive diagnosis, such as a specific failure mode, FM_{pq} , of a vehicle component, CT_p , or a prioritized sequence of possible failure modes that may be present in the test-subject vehicle, for example, $\langle FM_{p1q1}, FM_{p2q2}, FM_{p3q3}, \dots, FM_{pnqn} \rangle$. In some embodiments of the vehicle diagnostic data collector/analyzer 10, the deductive logic can be implemented as Bayesian reasoning, including an iterated or recursive application of Bayes theorem.

[0110] FIG. 5 is a flowchart illustrating a sequence of steps that can be performed in order to collect historical vehicle operational data corresponding to various normal vehicle operating conditions and vehicle component failure conditions, analyze the data and compare the results of the data analysis to test data gathered from a specific test-subject vehicle in order to diagnose potential failure conditions of vehicle components. The process can begin by proceeding to step 50, “Compile Historical Data,” wherein historical

vehicle diagnostic data samples corresponding to various normal vehicle operating conditions and vehicle component failure conditions gathered and organized, as described above.

[0111] As explained above, the historical diagnostic data can include various measured operating parameters from a number of different vehicles operating under a variety of normal conditions or failure conditions. Furthermore, the historical data can be collected as a “snapshot”—a single set of measurements at a moment in time—or as a “data strip”—a sequence or series of periodic measurements taken over a period of time.

[0112] The data can be accumulated in a database, such as a relational database that associates each instance of measured parameters with a definition or description of the prevailing ambient and operating conditions under which the data were gathered, as further described above. In some embodiments, the data can be sent to a central repository, for example, over a communication network.

[0113] Then, in step 52, “Analyze Historical Data,” the historical diagnostic data samples can be analyzed to determine typical ranges for operating parameter measurements corresponding to various normal and failure conditions, as described above. In this step, a diagnostic case history can be defined, for example, as an ordered list of diagnostic cases, that is historical data samples corresponding to a particular diagnosis, or failure condition.

[0114] In further explanation of this step, FIG. 6 is a flowchart illustrating a sequence of more detailed steps that can be performed in some embodiments in order to analyze the historical data. This process can begin by proceeding to step 54, “Isolate Operating Condition Data,” wherein the historical diagnostic data samples can be separated into different sets taken from different vehicle types at discrete operating conditions.

[0115] Then, in step 56, “Represent Data in Vector Space,” the historical data samples can be represented as points in a multidimensional vector space having dimensionality equal to the number of measured parameters and a variable probabilistic parameter categorization can be constructed by associating with each diagnostic case a “k”-dimensional probability distribution. Accordingly, in step 58, “Determine Mean Value,” a mean value can be statistically calculated for each sample set, as explained above. Correspondingly, in step 60, “Optimize Variable Variance Vector,” a “k”-dimensional variable variance vector can be optimized to best fit the diagnostic case history using a method from the field of optimization theory, as further explained above.

[0116] In addition, in step 62, “Associate with Failure Mode,” a diagnostic parameter categorization can be defined as a list of 2-tuplets associating each specific failure mode with a corresponding failure condition parameter space, as described above. As also explained above, the analyses can include methods of automated reasoning, for example, from the field of manifold learning, and the failure condition operating parameter spaces, as well as the parameter categorization, can be derived from the diagnostic case history utilizing methods from the field of neural networks or using genetic algorithms.

[0117] Returning to FIG. 5, subsequently, in step 64, “Read Parameters,” real-time measurements of operating parameters from a specific test-subject vehicle selected for diagnosis can be recorded, as described above. Again here, the measurements can be recorded as a “snapshot” or as a “data strip.” Next, in step 66, “Compare to Ranges,” similarities and

differences can be evaluated between the recorded measurements from the test-subject vehicle and the established ranges corresponding to normal operating conditions and failure conditions, including multiple ranges represented by a multidimensional manifold, as further explained above.

[0118] Additionally, in step 68, “Identify Operating Condition,” the operating parameter measurements from the test-subject vehicle can be correlated with known operating conditions, including normal operating conditions and failure conditions, as further explained above. Correspondingly, in step 70, “Diagnose Potential Failure Modes,” specific potential vehicle component failure modes that may be present in the test-subject vehicle can be diagnosed based on the operating parameter measurements corresponding to a known failure mode in the diagnostic parameter categorization, as also explained above.

[0119] FIG. 7 illustrates a representative diagnostic data collector/analyzer according to another embodiment of the invention. The embodiment of FIG. 7 is similar to the embodiment of FIG. 1 and thus, in the interest of brevity, those elements described hereinabove will not be described again. As shown in FIG. 7, the diagnostic data collector/analyzer 10 is configured to collect and/or analyze medical data. In this regard, the medical data analyzed may be obtained from one or more sensors 70 configured to sense vital signs or other such medically related data from a patient 72. These sensed vital signs may be collected, stored, analyzed, and/or displayed on a patient monitor 74. In addition, the diagnostic data collector/analyzer 10 can include the PC 12 and/or the hand-held diagnostic scan tool 14 configured to be coupled to the patient 72 via the patient monitor 74. The patient monitor 74 can include an onboard computer 18 that can be accessed by way of electrical links 20, such as such as conductors, wires, cables, data buses, a communication network or a wireless network. The diagnostic data collector/analyzer 10 is configured to aid a technician in identifying potential medical conditions in the patient 72.

[0120] The diagnostic data collector/analyzer 10 can further include the database 24 coupled to the PC 12 or scan tool 14, for example, by way of local links 26 and a communication network 28. In an alternative embodiment, the database 24 can be stored directed in a memory associated with the personal computer 12 or the scan tool 14. In this manner, suitable patient data may be store, accessed, analyzed, and/or displayed. Examples of suitable patient data include blood counts, results of tests and other such lab results, family history, and the like.

[0121] FIG. 8 is a flowchart illustrating method steps that may be followed in accordance with the embodiment of FIG. 7 for collecting and analyzing diagnostic data including historical data to diagnose medical conditions in a patient. The embodiment of FIG. 7 is similar to the embodiment of FIG. 1 and thus, in the interest of brevity, those elements described hereinabove will not be described again. As shown in FIG. 7, medical data corresponding to various normal vital signs or other such normal medical data and various disease conditions are compared to the medical data of the patient in order to diagnose potential disease conditions of the patient 72. The process can begin by proceeding to step 80, “Compile Historical Data,” wherein historical medical diagnostic data samples corresponding to various normal vital signs and disease conditions are gathered and organized. In addition, the historical data may include personal historical medical data

from the patient such as, for example, previous vital signs, previous lab results, family history, and the like.

[0122] The historical diagnostic data can include various sensed vital signs and/or other medical data from a statistically significant population of individuals that are healthy and a likewise statistically significant population of diseased individuals. Furthermore, the historical data can be collected as a “snapshot”—a single set of measurements at a moment in time—or as a “data strip”—a sequence or series of periodic measurements taken over a period of time. This data can have all personal information removed to prevent identification of participants in the medical sampling.

[0123] The data can be accumulated in a database, such as a relational database that associates each instance of measured parameters with a definition or description of pre-existing and/or exacerbating conditions under which the data were gathered. In some embodiments, the data can be sent to a central repository, for example, over a communication network.

[0124] Then, in step **82**, “Analyze Historical Data,” the historical diagnostic data samples can be analyzed to determine typical ranges for the vital signs or other such medical data corresponding to various normal and diseased conditions. In this step, a diagnostic case history can be defined, for example, as an ordered list of diagnostic cases, that is historical data samples corresponding to a particular diagnosis, or disease condition.

[0125] In further explanation of this step, FIG. 9 is a flowchart illustrating a sequence of more detailed steps that can be performed in some embodiments in order to analyze the historical data. This process can begin by proceeding to step **84**, “Normalize For Population Group,” wherein the historical diagnostic data samples can be separated into different sets taken from different population types such as, for example, various levels of wellness (e.g., very healthy, healthy, sick, etc.), particular ailments, diseases, and the like. In other examples, population types may include men, women, children, age of the patient, weight, height, ethnic group, level of fitness, smoker/non-smoker, lifestyle, socioeconomic status, stress level, etc. The historical data may then be compared to the normalized set of the historical diagnostic data samples.

[0126] Then, in step **86**, “Represent Data in Vector Space,” the historical data samples can be represented as points in a multidimensional vector space having dimensionality equal to the number of measured parameters and a variable probabilistic parameter categorization can be constructed by associating with each diagnostic case a “k”-dimensional probability distribution. Accordingly, in step **88**, “Determine Mean Value,” a mean value can be statistically calculated for each sample set. Correspondingly, in step **90**, “Optimize Variable Variance Vector,” a “k”-dimensional variable variance vector can be optimized to best fit the diagnostic case history using a method from the field of optimization theory.

[0127] In addition, in step **92**, “Associate with disease condition,” a diagnostic parameter categorization can be defined as a list of 2-tuplets associating each specific disease condition with a corresponding disease condition parameter space. The analyses can include methods of automated reasoning, for example, from the field of manifold learning, and the pre-existing and/or exacerbating conditions, as well as the parameter categorization, can be derived from the diagnostic case history utilizing methods from the field of neural networks or using genetic algorithms.

[0128] Returning to FIG. 8, subsequently, in step **94**, “Read Parameters,” real-time measurements of vital signs from the patient **72** can be recorded. The measurements can be recorded as a “snapshot” or as a “data strip.” Next, in step **96**, “Compare to Ranges,” similarities and differences can be evaluated between the recorded measurements from the patient **72** and the established ranges corresponding to normal and diseased conditions, including multiple ranges represented by a multidimensional manifold.

[0129] Additionally, in step **98**, “Identify Test Condition,” the testing parameters for the patient **72** can be correlated with known testing conditions (such as running, seated, etc.), including pre-existing and/or exacerbating conditions. Correspondingly, in step **100**, “Diagnose Potential Disease Conditions,” specific potential disease conditions that the patient may be suffering from can be diagnosed based on the vital signs corresponding to a known disease condition in the diagnostic parameter categorization.

[0130] FIG. 10 illustrates a representative diagnostic data collector/analyzer according to yet another embodiment of the invention. The embodiment of FIG. 10 is similar to the embodiments of FIGS. 1 and 7 and thus, in the interest of brevity, those elements described hereinabove will not be described again. As shown in FIG. 10, the diagnostic data collector/analyzer **10** is configured to collect and/or analyze data from an air conditioning (A/C) unit **102**, or, more generally, heating, ventilation, and air conditioning (HVAC) data. The A/C unit **102** may include the onboard computer **18**.

[0131] FIG. 11 is a flowchart illustrating method steps that may be followed in accordance with the embodiment of FIG. 10 for collecting and analyzing diagnostic data to diagnose conditions in the A/C unit **102**. As shown in FIG. 11 a sequence of steps are performed in order to collect historical operational data corresponding to various normal A/C unit operating conditions and A/C unit component failure conditions, analyze the data and compare the results of the data analysis to test data gathered from a specific test-subject A/C units in order to diagnose potential failure conditions of A/C unit components. The process can begin by proceeding to step **110**, “Compile Historical Data,” wherein historical vehicle diagnostic data samples corresponding to various normal A/C unit operating conditions and A/C unit component failure conditions gathered and organized.

[0132] The historical diagnostic data can include various measured operating parameters from a number of different A/C units operating under a variety of normal conditions or failure conditions. Furthermore, the historical data can be collected as a “snapshot”—a single set of measurements at a moment in time—or as a “data strip”—a sequence or series of periodic measurements taken over a period of time.

[0133] The data can be accumulated in a database, such as a relational database that associates each instance of measured parameters with a definition or description of the prevailing ambient and operating conditions under which the data were gathered. In some embodiments, the data can be sent to a central repository, for example, over a communication network.

[0134] Then, in step **112**, “Analyze Historical Data,” the historical diagnostic data samples can be analyzed to determine typical ranges for operating parameter measurements corresponding to various normal and failure conditions. In this step, a diagnostic case history can be defined, for

example, as an ordered list of diagnostic cases, that is historical data samples corresponding to a particular diagnosis, or failure condition.

[0135] In further explanation of this step, FIG. 12 is a flowchart illustrating a sequence of more detailed steps that can be performed in some embodiments in order to analyze the historical data. This process can begin by proceeding to step 114, "Isolate Operating Condition Data," wherein the historical diagnostic data samples can be separated into different sets taken from different A/C unit types at discrete operating conditions.

[0136] Then, in step 116, "Represent Data in Vector Space," the historical data samples can be represented as points in a multidimensional vector space having dimensionality equal to the number of measured parameters and a variable probabilistic parameter categorization can be constructed by associating with each diagnostic case a "k"-dimensional probability distribution. Accordingly, in step 118, "Determine Mean Value," a mean value can be statistically calculated for each sample set. Correspondingly, in step 120, "Optimize Variable Variance Vector," a "k"-dimensional variable variance vector can be optimized to best fit the diagnostic case history using a method from the field of optimization theory.

[0137] In addition, in step 122, "Associate with Failure Mode," a diagnostic parameter categorization can be defined as a list of 2-tuplets associating each specific failure mode with a corresponding failure condition parameter space. The analyses can include methods of automated reasoning, for example, from the field of manifold learning, and the failure condition operating parameter spaces, as well as the parameter categorization, can be derived from the diagnostic case history utilizing methods from the field of neural networks or using genetic algorithms.

[0138] Returning to FIG. 11, subsequently, in step 124, "Read Parameters," real-time measurements of operating parameters from a specific test-subject vehicle selected for diagnosis can be recorded. The measurements can be recorded as a "snapshot" or as a "data strip." Next, in step 126, "Compare to Ranges," similarities and differences can be evaluated between the recorded measurements from the test-subject vehicle and the established ranges corresponding to normal operating conditions and failure conditions, including multiple ranges represented by a multidimensional manifold.

[0139] Additionally, in step 128, "Identify Operating Condition," the operating parameter measurements from the test-subject A/C unit can be correlated with known operating conditions, including normal operating conditions and failure conditions. Correspondingly, in step 130, "Diagnose Potential Failure Modes," specific potential A/C unit component failure modes that may be present in the test-subject A/C unit 102 can be diagnosed based on the operating parameter measurements corresponding to a known failure mode in the diagnostic parameter categorization.

[0140] FIGS. 2 and 5-12 are block diagrams and flowcharts of methods, apparatuses and computer program products according to various embodiments of the present invention. It will be understood that each block or step of the block diagram, flowchart and control flow illustrations, and combinations of blocks in the block diagram, flowchart and control flow illustrations, can be implemented by computer program instructions or other means. Although computer program instructions are discussed, an apparatus according to the present invention can include other means, such as hardware

or some combination of hardware and software, including one or more processors or controllers, for performing the disclosed functions.

[0141] In this regard, FIGS. 2, 7, and 10 depicts the apparatuses of various embodiments that including several of the key components of a general-purpose computer by which an embodiment of the present invention may be implemented. Those of ordinary skill in the art will appreciate that a computer can include many more components than those shown in FIGS. 2, 7, and 10. However, it is not necessary that all of these generally conventional components be shown in order to disclose an illustrative embodiment for practicing the invention. The general-purpose computer can include a processing unit and a system memory, which may include random access memory (RAM) and read-only memory (ROM). The computer also may include nonvolatile storage memory, such as a hard disk drive, where additional data can be stored.

[0142] An embodiment of the present invention can also include one or more input or output devices 16, such as a mouse, keyboard, monitor, and the like. A display can be provided for viewing text and graphical data, as well as a user interface to allow a user to request specific operations, including for example, a speaker, headphones or a microphone. Furthermore, an embodiment of the present invention may be connected to one or more remote computers via a network interface. The connection may be over a local area network (LAN) wide area network (WAN), and can include all of the necessary circuitry for such a connection.

[0143] Typically, computer program instructions may be loaded onto the computer or other general purpose programmable machine to produce a specialized machine, such that the instructions that execute on the computer or other programmable machine create means for implementing the functions specified in the block diagrams, schematic diagrams or flowcharts. Such computer program instructions may also be stored in a computer-readable medium that when loaded into a computer or other programmable machine can direct the machine to function in a particular manner, such that the instructions stored in the computer-readable medium produce an article of manufacture including instruction means that implement the function specified in the block diagrams, schematic diagrams or flowcharts.

[0144] In addition, the computer program instructions may be loaded into a computer or other programmable machine to cause a series of operational steps to be performed by the computer or other programmable machine to produce a computer-implemented process, such that the instructions that execute on the computer or other programmable machine provide steps for implementing the functions specified in the block diagram, schematic diagram, flowchart block or step.

[0145] Accordingly, blocks or steps of the block diagram, flowchart or control flow illustrations support combinations of means for performing the specified functions, combinations of steps for performing the specified functions and program instruction means for performing the specified functions. It will also be understood that each block or step of the block diagrams, schematic diagrams or flowcharts, as well as combinations of blocks or steps, can be implemented by special purpose hardware-based computer systems, or combinations of special purpose hardware and computer instructions, that perform the specified functions or steps.

[0146] As an example, provided for purposes of illustration only, a data input software tool of a search engine application can be a representative means for receiving a query including

one or more search terms. Similar software tools of applications, or implementations of embodiments of the present invention, can be means for performing the specified functions. For example, an embodiment of the present invention may include computer software for interfacing a processing element with a user-controlled input device, such as a mouse, keyboard, touchscreen display, scanner, or the like. Similarly, an output of an embodiment of the present invention may include, for example, a combination of display software, video card hardware, and display hardware. A processing element may include, for example, a controller or microprocessor, such as a central processing unit (CPU), arithmetic logic unit (ALU), or control unit.

[0147] The many features and advantages of the invention are apparent from the detailed specification, and thus, it is intended by the appended claims to cover all such features and advantages of the invention which fall within the true spirit and scope of the invention. Further, since numerous modifications and variations will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation illustrated and described, and accordingly, all suitable modifications and equivalents may be resorted to, falling within the scope of the invention.

What is claimed is:

1. A computer-implemented method of analyzing medical data, comprising:

compiling, via a processor of a diagnostic device, a collection of historical test data points from a plurality of population types;

correlating, via the processor, each historical test data point with a population type to produce entries of a diagnostic case history;

grouping, via the processor, the entries of the diagnostic case history by population type;

defining, via the processor, a range corresponding to the population type of a patient based on the collection of test data points of the entries of the diagnostic case history grouped by population type; and

diagnosing, via the processor, a disease condition of the patient based on the range corresponding to the disease condition for the population type.

2. The computer-implemented method of claim 1, wherein the test data points correspond to a plurality of patients having a plurality of discrete population types.

3. The computer-implemented method of claim 1, wherein the population type corresponds to a state of wellness of one or more patients of the population type.

4. The computer-implemented method of claim 1, wherein the population type corresponds to a particular disease existing in one or more patients of the population type.

5. The computer-implemented method of claim 1, wherein each of the test data points comprises a single set of vital signs recorded at a moment in time.

6. The computer-implemented method of claim 1, wherein each of the test data points comprises a sequence of vital signs recorded over a period of time.

7. The computer-implemented method of claim 1, wherein the step of defining comprises a method of automated reasoning.

8. The computer-implemented method of claim 1, further comprising:

representing each of the test data points as a point in a multidimensional vector space; and

statistically analyzing a set of the test data points corresponding to the population type to define a parameter space corresponding to the population type in the multidimensional vector space, wherein the parameter space comprises the range.

9. The computer-implemented method of claim 8, wherein the step of statistically analyzing further comprises:

associating with the set a multidimensional probability distribution having a mean value and a multidimensional variable variance vector; and

optimizing the parameter space by identifying an optimal variance vector based on the set.

10. The computer-implemented method of claim 8, wherein the step of statistically analyzing further comprises mapping the disease condition to the parameter space.

11. The computer-implemented method of claim 8, further comprising:

performing a dimensionality reduction procedure on the set of test data points and a correlated set of diagnoses corresponding to at least some of the population types.

12. The computer-implemented method of claim 8, further comprising:

performing a dimensionality reduction procedure on a plurality of disease condition and a correlated plurality of parameter spaces.

13. The computer-implemented method of claim 1, further comprising:

measuring at least one of a plurality of vital signs of the patient;

comparing at least one of the measured vital signs to normalized value for the population type of the patient; and determining a level of wellness of the patient based on one or more of the compared vital signs lying within a normalized range of values for the population type of the patient.

14. A computer program product for analyzing vehicle test data to diagnose a failure mode of a vehicle component, comprising a computer-readable medium encoded with instructions configured to be executed by a processor in order to perform predetermined operations comprising:

compiling, via the processor of a diagnostic device, a collection of historical test data points from a plurality of population types;

correlating, via the processor, each historical test data point with a population type to produce entries of a diagnostic case history;

grouping, via the processor, the entries of the diagnostic case history by population type;

defining, via the processor, a range corresponding to the population type of a patient based on the collection of test data points of the entries of the diagnostic case history grouped by population type; and

diagnosing, via the processor, a disease condition of the patient based on the range corresponding to the disease condition for the population type.

15. The computer program product of claim 14, wherein the test data points correspond to a plurality of patients having a plurality of discrete population types.

16. The computer program product of claim 14, wherein the population type corresponds to a state of wellness of one or more patients of the population type.

17. The computer program product of claim 14, wherein the population type corresponds to a particular disease existing in one or more patients of the population type.

18. The computer program product of claim **14**, wherein each of the test data points comprises a single set of vital signs recorded at a moment in time.

19. The computer program product of claim **14**, wherein each of the test data points comprises a sequence of vital signs recorded over a period of time.

20. The computer program product of claim **14**, wherein the step of defining comprises a method of automated reasoning.

21. The computer program product of claim **14**, further comprising:

representing each of the test data points as a point in a multidimensional vector space; and
statistically analyzing a set of the test data points corresponding to the population type to define a parameter space corresponding to the population type in the multidimensional vector space, wherein the parameter space comprises the range.

22. The computer program product of claim **21**, wherein the step of statistically analyzing further comprises:

associating with the set a multidimensional probability distribution having a mean value and a multidimensional variable variance vector; and optimizing the parameter space by identifying an optimal variance vector based on the set.

23. The computer program product of claim **21**, wherein the step of statistically analyzing further comprises mapping the disease condition to the parameter space.

24. The computer program product of claim **21**, further comprising performing a dimensionality reduction procedure on the set of test data points and a correlated set of diagnoses corresponding to at least some of the population types.

25. The computer program product of claim **21**, further comprising performing a dimensionality reduction procedure on a plurality of disease condition and a correlated plurality of parameter spaces.

26. The computer program product of claim **14**, further comprising:

measuring at least one of a plurality of vital signs of the patient;
comparing at least one of the measured vital signs to normalized value for the population type of the patient; and
determining a level of wellness of the patient based on one or more of the compared vital signs lying within a normalized range of values for the population type of the patient.

27. A diagnostic tool for analyzing medical data, comprising:

a processor configured to execute software modules;
a memory configured to store the software modules, and communicatively connected to the processor;
wherein the software modules comprises:

a data compiler configured to compile a collection of historical test data points which includes a plurality of medical measurements corresponding to a plurality of population types;

a data analyzer configured to correlate each historical test data point with a disease condition to produce entries of a diagnostic case history, group the entries of the diagnostic case history by population type, and define a range corresponding to the disease condition of a population type based on the collection of test data points of the entries of the diagnostic case history grouped by population type; and

a virtual diagnostician configured to diagnose a disease condition in a patient based on the medical data of the patient corresponding to a disease condition in the population type of the patient.

28. A computer-implemented method of analyzing A/C unit test data, comprising:

compiling, via a processor of a diagnostic device, a collection of historical test data points which includes a plurality of operating parameter measurements recorded by an individual A/C unit's onboard computer, wherein the diagnostic device and the A/C unit are separate but connectable objects;

correlating, via the processor, each historical test data point with an operating condition to produce entries of a diagnostic case history;

grouping, via the processor, the entries of the diagnostic case history by operating condition;

defining, via the processor, a range corresponding to the operating condition of a A/C unit type based on the collection of test data points of the entries of the diagnostic case history grouped by operating condition; and

diagnosing, via the processor, a A/C unit component failure mode based on the range corresponding to a failure condition, wherein the operating parameters are selected from the group consisting of: a switch position, a motor run condition, a motor speed, a test equipment connection, a A/C unit electrical connection condition, an ambient air temperature, an output air temperature, a refrigerant pressure, and a refrigerant type.

29. The computer-implemented method of claim **28**, wherein the test data points correspond to a plurality of A/C units under a plurality of discrete operating conditions.

30. The computer-implemented method of claim **28**, further comprising:

representing each of the test data points as a point in a multidimensional vector space; and

statistically analyzing a set of the test data points corresponding to the operating condition to define a parameter space corresponding to the operating condition in the multidimensional vector space, wherein the parameter space comprises the range.

31. The computer-implemented method of claim **30**, wherein the step of statistically analyzing further comprises:

associating with the set a multidimensional probability distribution having a mean value and a multidimensional variable variance vector; and

optimizing the parameter space by identifying an optimal variance vector based on the set.

32. The computer-implemented method of claim **30**, wherein the step of statistically analyzing further comprises mapping the failure mode to the parameter space.

33. The computer-implemented method of claim **30**, further comprising performing a dimensionality reduction procedure on the set of test data points and a correlated set of diagnoses corresponding to at least some of the operating conditions.

34. The computer-implemented method of claim **30**, further comprising performing a dimensionality reduction procedure on a plurality of failure modes and a correlated plurality of parameter spaces.

35. A computer program product for analyzing A/C unit test data, comprising a computer-readable medium encoded with instructions configured to be executed by a processor in order to perform predetermined operations comprising:

compiling, via the processor of a diagnostic device, a collection of historical test data points which includes a plurality of operating parameter measurements recorded by an individual A/C unit's onboard computer, wherein the diagnostic device and the A/C unit are separate but connectable objects;

correlating, via the processor, each historical test data point with an operating condition to produce entries of a diagnostic case history;

grouping, via the processor, the entries of the diagnostic case history by operating condition;

defining, via the processor, a range corresponding to the operating condition of a A/C unit type based on the collection of test data points of the entries of the diagnostic case history grouped by operating condition; and

diagnosing, via the processor, a A/C unit component failure mode based on the range corresponding to a failure condition, wherein the operating parameters are selected from the group consisting of: a switch position, a motor run condition, a motor speed, a test equipment connection, a A/C unit electrical connection condition, an ambient air temperature, an output air temperature, a refrigerant pressure, and a refrigerant type.

36. A diagnostic tool for analyzing A/C unit test data, comprising:

a processor configured to execute software modules;

a memory configured to store the software modules, and communicatively connected to the processor;

wherein the software modules comprise:

a data compiler configured to compile a collection of historical test data points which includes a plurality of operating parameter measurements recorded by an individual A/C unit's onboard computer, wherein the diagnostic tool and the A/C unit are separate but connectable objects;

a data analyzer configured to correlate each historical test data point with an operating condition to produce entries of a diagnostic case history, group the entries of the diagnostic case history by operating condition, and define a range corresponding to the operating condition of a A/C unit type based on the collection of test data points of the entries of the diagnostic case history grouped by operating condition; and

a virtual diagnostician configured to diagnose a A/C unit component failure mode based on the range corresponding to a failure condition, wherein the operating parameters are selected from the group consisting of: a switch position, a motor run condition, a motor speed, a test equipment connection, a air temperature, a refrigerant pressure, and a refrigerant type.

37. The diagnostic tool of claim **36**, wherein the data analyzer is further configured to represent each of the test data points as a point in a multidimensional vector space and to statistically analyze a set of the test data points corresponding to the operating condition to define a parameter space corresponding to the operating condition in the multidimensional vector space, wherein the parameter space comprises the range.

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专利名称(译)	诊断数据收集和分析方法和装置		
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申请(专利权)人(译)	SPX公司		
当前申请(专利权)人(译)	SPX公司		
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摘要(译)

医疗诊断数据收集器/分析器编译历史车辆诊断数据，包括来自各种人口类型的许多不同人的测量的生命体征，并对各种生命体征组合进行统计分析，以建立对应于健康个体和各种疾病状况的范围。。

