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<table style="width: 100%; border: none;"> <tr> <td style="width: 50%; vertical-align: top; padding: 5px;"> (21) International Application Number: PCT/US00/08662 (22) International Filing Date: 31 March 2000 (31.03.00) (30) Priority Data: <div style="display: flex; justify-content: space-between; margin-top: 5px;"> 09/285,612 2 April 1999 (02.04.99) US </div> <div style="display: flex; justify-content: space-between; margin-top: 5px;"> 09/285,611 2 April 1999 (02.04.99) US </div> (71) Applicant: GENERAL ELECTRIC COMPANY [US/US]; P.O. Box 8, Schenectady, NY 12301 (US). (72) Inventors: GIBSON, David, Richard; 171 South Lakeside Drive, North East, PA 16428 (US). RODDY, Nicholas, Edward; 30 Grissom Drive, Clifton Park, NY 12065 (US). VARMA, Anil; 139D Eastwood Drive, Clifton Park, NY 12065 (US). (74) Agents: MORA, Enrique, J. et al.; Holland & Knight, LLP, P.O. Box 1526, Orlando, FL 32802-1526 (US). </td> <td style="width: 50%; vertical-align: top; padding: 5px;"> (81) Designated States: AU, CA, ID, MX. Published <i>With international search report.</i> </td> </tr> </table>			(21) International Application Number: PCT/US00/08662 (22) International Filing Date: 31 March 2000 (31.03.00) (30) Priority Data: <div style="display: flex; justify-content: space-between; margin-top: 5px;"> 09/285,612 2 April 1999 (02.04.99) US </div> <div style="display: flex; justify-content: space-between; margin-top: 5px;"> 09/285,611 2 April 1999 (02.04.99) US </div> (71) Applicant: GENERAL ELECTRIC COMPANY [US/US]; P.O. Box 8, Schenectady, NY 12301 (US). (72) Inventors: GIBSON, David, Richard; 171 South Lakeside Drive, North East, PA 16428 (US). RODDY, Nicholas, Edward; 30 Grissom Drive, Clifton Park, NY 12065 (US). VARMA, Anil; 139D Eastwood Drive, Clifton Park, NY 12065 (US). (74) Agents: MORA, Enrique, J. et al.; Holland & Knight, LLP, P.O. Box 1526, Orlando, FL 32802-1526 (US).	(81) Designated States: AU, CA, ID, MX. Published <i>With international search report.</i>
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(54) Title: METHOD AND SYSTEM FOR ANALYZING FAULT LOG DATA FOR DIAGNOSTICS AND REPAIRS OF LOCOMOTIVES				
(57) Abstract <div style="display: flex;"> <div style="flex: 1; padding-right: 20px;"> <p>The present invention discloses a system (10) and method for analyzing fault log data from a malfunctioning locomotive or other large land-based, self-powered transport equipment. The method allows for receiving new fault log data (232) comprising a plurality of faults from the malfunctioning equipment. The method further allows for selecting a plurality of distinct faults (233) from the new fault log data. Respective generating steps allow for generating at least one distinct fault cluster (236) from the plurality of distinct faults and for generating a plurality of weighted repair and distinct fault cluster combinations. An identifying step allows for identifying at least one repair (238) for the at least one distinct fault cluster using the plurality of weighted repair and distinct fault cluster combinations.</p> </div> <div style="flex: 1;"> <pre> graph TD 230[] --> 232[RECEIVE NEW FAULT LOG DATA COMPRISING A PLURALITY OF FAULTS FROM A MALFUNCTIONING MACHINE] 232 --> 233[IDENTIFY A PLURALITY OF DISTINCT FAULTS FROM THE NEW FAULT LOG DATA] 233 --> 234[DETERMINE A NUMBER OF TIMES EACH DISTINCT FAULT OCCURRED] 234 --> 236[GENERATE A PLURALITY OF DISTINCT FAULT CLUSTERS FROM THE PLURALITY OF DISTINCT FAULTS (1S,2S,3S, etc.)] 236 --> 238[PREDICTING AT LEAST ONE REPAIR FOR THE PLURALITY OF DISTINCT FAULT CLUSTERS USING A PLURALITY OF PREDETERMINED WEIGHTED REPAIR AND DISTINCT FAULT CLUSTER COMBINATIONS] </pre> </div> </div>				

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METHOD AND SYSTEM FOR ANALYZING
FAULT LOG DATA FOR DIAGNOSTICS
AND REPAIRS OF LOCOMOTIVES

BACKGROUND OF THE INVENTION

The present invention relates generally to diagnostics of locomotive or other large land-based, self-powered transport equipment, and, more specifically, to a system and method for processing historical repair data and fault log data to facilitate analysis of malfunctioning machine equipment.

A machine, such as a locomotive or an off-road haul vehicle, includes elaborate controls and sensors that generate faults when anomalous operating conditions of the machine are encountered. Typically, a field engineer will look at a fault log and determine whether a repair is necessary.

Approaches like neural networks, decision trees, etc., have been employed to learn over input data to provide prediction, classification, and function approximation capabilities in the context of diagnostics. Often, such approaches have required structured and relatively static and complete input data sets for learning, and have produced models that resist real-world interpretation.

Another approach, Case Based Reasoning (CBR), is based on the observation that experiential knowledge (memory of past experiences - or cases) is applicable to problem solving as learning rules or behaviors. CBR relies on relatively little pre-processing of raw knowledge, focusing instead on indexing, retrieval, reuse, and archival of cases. In the diagnostic context, a case refers to a problem/solution description pair that represents a diagnosis of a problem and an appropriate repair.

CBR assumes cases described by a fixed, known number of descriptive attributes. Conventional CBR systems assume a corpus of fully

valid or "gold standard" cases that new incoming cases can be matched against.

U.S. Patent No. 5,463,768 discloses an approach which uses error log data and assumes predefined cases with each case associating an input error log to a verified, unique diagnosis of a problem. In particular, a plurality of historical error logs are grouped into case sets of common malfunctions. From the group of case sets, common patterns, i.e., consecutive rows or strings of data, are labeled as a block. Blocks are used to characterize fault contribution for new error logs that are received in a diagnostic unit.

For a continuous fault code stream where any or all possible fault codes may occur from zero to any finite number of times and where the fault codes may occur in any order, predefining the structure of a case is nearly impossible.

Therefore, there is a need for a system and method for processing historical repair data and fault log data, which is not restricted to sequential occurrences of fault log entries and which provides weighted repair and distinct fault cluster combinations, to facilitate analysis of new fault log data from a malfunctioning machine.

SUMMARY OF THE INVENTION

The above-mentioned needs are fulfilled by the present invention which provides in one embodiment a method for analyzing fault log data from a malfunctioning locomotive or other large land-based, self-powered transport equipment. The method allows for receiving new fault log data comprising a plurality of faults from the malfunctioning equipment. The method further allows for selecting a plurality of distinct faults from the new fault log data. Respective generating steps allow for generating at least one distinct fault cluster from the plurality of distinct faults and for generating a plurality of weighted repair and distinct fault

cluster combinations. An identifying step allows for identifying at least one repair for the at least one distinct fault cluster using the plurality of weighted repair and distinct fault cluster combinations.

The present invention further fulfills the foregoing needs by
5 providing a system for analyzing fault log data from a malfunctioning locomotive or other large land-based, self-powered transport equipment. The system comprises a directed weight data storage unit adapted to store a plurality of weighted repair and distinct fault cluster combinations. The system further comprises a processor adapted to receive new fault log data
10 comprising a plurality of faults from the malfunctioning equipment and a processor adapted to select a plurality of distinct faults from the new fault log data. Respective processors are configured to generate at least one distinct fault cluster from the selected plurality of distinct faults and a plurality of weighted repair and distinct fault cluster combinations. The
15 system further comprises a processor for identifying at least one repair for the at least one distinct fault cluster using the plurality of predetermined weighted repair and distinct fault cluster combinations.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is one embodiment of a block diagram of a system of
20 the present invention for automatically processing repair data and fault log data from a locomotive or other large land-based, self-powered transport equipment and diagnosing malfunctioning equipment;

FIG. 2 is an illustration of a portion of repair log data;

FIG. 3 is an illustration of a portion of fault log data;

25 FIG. 4 is a flowchart describing the steps for generating a plurality of cases, and repair and fault cluster combinations for each case;

FIG. 5 is an illustration of a case generated according to the flowchart of FIG. 4;

FIGS. 6A-6C are illustrations of repair and fault cluster combinations for the case shown in FIG. 5;

FIG. 7 is a flowchart describing the steps for determining a weight for each of the repair and fault cluster combinations;

5 FIGS. 8A-8C are illustrations of partial lists of single, double, and triple fault clusters for related repairs;

FIGS. 9A-9C are illustrations of partial lists of single, double, and triple fault clusters for related and unrelated repairs;

10 FIGS. 10A-10C are illustrations of partial lists of weighted repair and distinct fault cluster combinations;

FIG. 11 is a flowchart describing the steps for adding a new case to the case database and updating the weighted repair and distinct fault cluster combinations;

15 FIG. 12 is an illustration of a portion of new fault log data from a malfunctioning machine;

FIG. 13 is a flowchart describing the steps for analyzing the new fault log data from a malfunctioning machine and predicting one or more possible repair actions;

20 FIG. 14 is an illustration of the distinct faults identified in the new fault log, shown in FIG. 12, and the number of occurrences thereof;

FIGS. 15A-15D are illustrations of distinct fault clusters for the distinct faults identified in FIG. 14;

25 FIG. 16 is a printout of weighted repair and fault cluster combinations by the system shown in FIG. 1 for the fault log shown in FIG. 12, and a listing of recommended repairs;

FIG. 17 is a flowchart further describing the step of predicting repairs from the weighted repair and fault cluster combinations shown in FIG. 16; and

FIG. 18 is one embodiment of a flowchart describing the steps for automatically analyzing new fault log data from a malfunctioning machine and predicting one or more possible repair actions.

DETAILED DESCRIPTION OF THE INVENTION

5 FIG. 1 diagrammatically illustrates one embodiment of a diagnostic system 10 of the present invention. In one aspect, system 10 provides a process for automatically harvesting or mining repair data comprising a plurality of related and unrelated repairs and fault log data comprising a plurality of faults from a locomotive or other large land-based, self-powered transport equipment, and generating weighted repair and distinct fault cluster combinations which are diagnostically significant
10 predictors to facilitate analysis of new fault log data from malfunctioning machine equipment.

 Although the present invention is described with reference to
15 a locomotive, system 10 can be used in conjunction with any machine in which operation of the machine is monitored, such as a chemical, an electronic, a mechanical, or a microprocessor machine.

 Exemplary system 10 includes a processor 12 such as a computer (e.g., UNIX workstation) having a hard drive, input devices such
20 as a keyboard, a mouse, magnetic storage media (e.g., tape cartridges or disks), optical storage media (e.g., CD-ROMs), and output devices such as a display and a printer. Processor 12 is operably connected to and processes data contained in a repair data storage unit 20 and a fault log data storage unit 22.

25 Repair data storage unit 20 includes repair data or records regarding a plurality of related and unrelated repairs for one or more locomotives. FIG. 2 shows an exemplary portion 30 of the repair data contained in repair data storage unit 20. The repair data may include a customer identification number 32, a locomotive identification or unit

number 33, the date 34 of the repair, the repair code 35, a repair code description 36, a description of the actual repair 37 performed, etc.

Fault log data storage unit 22 includes fault log data or records regarding a plurality of faults occurring prior to the repairs for the one or more locomotives. FIG. 3 shows an exemplary portion 40 of the fault log data contained in fault log data storage unit 22. The fault log data may include a customer identification number 42, a locomotive identification number or unit 44, the date 45 that the fault occurred, a fault code 46, a fault code description 48, etc. Additional information may include various sensor readings, e.g., temperature sensor readings, pressure sensor readings, electrical sensor readings, engine power readings, etc. From the present invention, it will be appreciated by those skilled in the art that a repair data storage unit and a fault log data storage unit may contain repair data and fault log data for a plurality of different locomotives.

FIG. 4 is a flowchart of an exemplary process 50 of the present invention for selecting or extracting repair data from repair data storage unit 20 and fault log data from fault log data storage unit 22, and generating a plurality of diagnostic cases, which are stored in a case storage unit 24. As used herein, the term "case" comprises a repair and one or more distinct faults or fault codes. As also used herein, the term "distinct fault" is a fault or a fault code which differs from other faults or fault codes so that, as described in greater detail below, if the fault log data includes more than one occurrence of the same fault or fault code, the similarly occurring fault or fault code is identified only once.

With reference still to FIG. 4, process 50 comprises, at 52, selecting or extracting a repair from repair data storage unit 20 (FIG. 1). Given the identification of a repair, the present invention searches fault log data storage unit 22 (FIG. 1) to select or extract, at 54, distinct faults occurring over a predetermined period of time prior to the repair.

The predetermined period of time may extend from a predetermined date prior to the repair to the date of the repair. Desirably, the period of time extends from prior to the repair, e.g., 14 days, to the date of the repair. It will be appreciated that other suitable time periods may be
5 chosen. Desirably, the same period of time is chosen for generating all of the cases. As will be appreciated further by the discussion below, it is the selection of distinct faults which is important and not the order or sequence of their arrangement in the fault log data.

At 56, the number of times each distinct fault occurred
10 during the predetermined period of time is determined. A repair and the one or more distinct faults are generated and stored as a case, at 60.

FIG. 5 illustrates a case 70 generated by process 50 (FIG. 4). Exemplary case 70 comprises a file name 72 which lists, for example, a repair or repair code 2322 which corresponds to replacement of an
15 electronic fuel injection pump, a customer identification number 74, a locomotive identification number or unit 76, a start date 78 and an end date 80 over which faults are selected, a listing of the distinct fault or fault codes 82 which occurred between start date 78 and end date 80, and the number of times each distinct fault or fault code occurred 84.

20 In this exemplary case 70, fault code 7A5D indicates that the locomotive diesel engine failed to reach full operating power, fault code 7A4A indicates an air conditioner compressor failed to start, and fault code 76D5 indicates a fault reset. Case 70 may also list additional information
86 such as various average sensor readings, e.g., average temperature
25 sensor readings, average pressure sensor readings, average electrical sensor readings, average engine power readings, etc., for distinct faults 82.

With reference again to FIG. 4, at 62, repair and distinct
fault cluster combinations are generated. For exemplary case 70 (FIG. 5),
three repair code 2322 and single fault cluster (e.g., repair code 2322 and
30 fault code 7A5D, repair code 2322 and fault code 7A4A, and repair code

2322 and fault code 76D5) combinations are illustrated in FIG. 6A. Three repair code 2322 and double fault clusters (e.g., repair code 2322 and fault codes 7A5D and 7A4A, repair code 2322 and fault codes 7A5D and 76D5, and repair code 2322 and fault codes 7A4A and 76D5) combinations are
5 illustrated in FIG. 6B, and one repair code 2322 and triple fault cluster (e.g., repair code 2322 and fault codes 7A5D, 7A4A, and 76D5) combination is illustrated in FIG. 6C. From the present description, it will be appreciated by those skilled in the art that a case having a greater number of distinct faults would result in a greater number of repair and
10 fault cluster combinations.

Process 50 is repeated by selecting another repair entry from the repair data to generate another case, and to generate a plurality of repair and fault cluster combinations. Case data storage unit 24 desirably stores a plurality of cases comprising related and unrelated repairs and a plurality of
15 repair and distinct fault cluster combinations.

FIG. 7 is a flowchart of an exemplary process 100 of the present invention for generating weighted repair and fault cluster combinations based on the plurality of cases generated in process 50. Process 100 comprises, at 101, selecting a repair and fault cluster
20 combination, and determining, at 102, the number of times the combination occurs in cases comprising related repairs. The number of times the combination occurs in the plurality of cases of related and unrelated repairs, e.g., all repairs is determined at 104. A weight is determined at 108 for the repair and distinct fault cluster combination by dividing the number of
25 times the combination occurs in cases comprising related repairs by the number of times the distinct fault cluster occurs in the plurality of cases comprising related and unrelated repairs.

Process 100 is further described in greater detail with reference to FIGS. 8-10 and exemplary case data storage unit 24 (FIG. 1) which contains, for example, 500 cases covering 60 different repairs in which 38 cases relate to repair code 2322.

5 FIG. 8A is a portion 110 of the plurality single fault clusters generated from the 38 cases in case data storage unit 24 related to repair code 2322. As shown in FIG. 8A, repair code 2322 and single fault cluster or fault code 76D5 combination occurred 24 times, repair code 2322 and single fault cluster or fault code 7A5D combination occurred 23 times, and
10 repair code 2322 and single fault cluster or fault code 7A4A combination occurred once. Also observed are other fault codes which occurred in other cases involving repair code 2322.

 FIG. 8B illustrates a portion 112 of the plurality of double fault clusters generated from cases in case storage unit 24 related to repair
15 code 2322. As shown FIG. 8B repair code 2322 and double fault cluster or fault codes 7A5D and 76D5 combination occurred 20 times, repair code 2322 and double fault cluster or fault codes 7A5D and 7A4A combination occurred once, and repair code 2322 and double fault cluster or fault codes 7A4A and 76D5 occurred once. FIG. 8C illustrates a portion 114 of the
20 plurality of triple fault clusters generated from cases in case storage unit 24 related to repair code 2322 in which repair code 2322 and triple fault cluster or fault 7A5D, 7A4A, and 76D5 combination occurred once.

 For cases involving repair code 2322 and having distinct faults numbering greater than three (e.g., n), additional fault clusters of
25 four, five, . . . , n , (not shown) are generated.

 FIG. 9A-9C are portions 120, 122, and 124, of the single, double, and triple fault clusters, respectively, generated from all of the plurality of cases (e.g., related and unrelated repairs) in case storage unit 24. As shown in FIG. 9A, single fault cluster or fault code 76D5 occurred in
30 24 out of all the cases, single fault cluster or fault code 7A5D occurred in

84 out of all the plurality of cases, and single fault cluster or fault code 7A4A occurred in 4 out of all of the plurality of cases.

As shown in FIG. 9B double fault cluster or fault codes 7A5D and 76D5 occurred in 73 out of all of the plurality of cases, double
5 fault cluster or fault codes 7A5D and 7A4A occurred once out of all of the plurality of cases, and double fault cluster or fault codes 7A4A and 76D5 occurred once out of all of the plurality of cases.

As shown in FIG. 9C, triple fault cluster or fault codes 7A5D, 7A4A, and 76D5 occurred once out of all of the plurality of cases.

10 For cases having distinct faults numbering greater than three (e.g., n), additional fault clusters of four, five, . . . , n , (not shown) are generated.

Weighted repair and fault cluster combinations are determined and stored in a directed weight data storage unit 26. Partial
15 listings of the weighted repair and fault cluster combinations are best shown in FIGS. 10A-10C.

For example, FIG. 10A illustrates a portion 130 of the weighted repair and single distinct fault cluster combinations. As shown in FIG. 10A, repair code 2322 and single fault cluster or fault code 7A5D
20 combination has a weight of 0.27 or 27% (e.g., 23/84), repair code 2322 and single fault cluster or fault code 76D5 and has a weight of 0.09 or 9% (e.g., 24/268), repair code 2322 and single fault cluster or fault code 7A4A has a weight of 0.25 or 25% (e.g., 1/4).

FIG. 10B illustrates a portion 140 of the weighted repair and
25 double distinct fault cluster combinations. As shown in FIG. 10B, repair code 2322 and double fault cluster or fault codes 7A5D and 76D5 combination has a weight of 0.27 or 27% (e.g., 20/73), repair code 2322 and double fault cluster or fault codes 7A5D and 7A4A has a weight of 1.0 or 100% (e.g., 1/1), and repair code 2322 and double fault cluster or fault
30 codes 7A4A and 76D5 has a weight of 0.25 or 25% (e.g., 1/4).

FIG. 10C illustrates a portion 145 of the weighted repair and triple distinct fault cluster combination. As shown in FIG. 10C, repair code 2322 and triple fault cluster or fault codes 7A5D, 7A4A, and 76D5 has a weight of 1.0 or 100% (e.g., 1/1).

5 For cases having distinct faults numbering greater than three (e.g., n), additional directed weights for fault clusters of four, five, . . . , n, (not shown) are generated.

Once the weighted repair and distinct fault cluster combinations are determined, they can be used to analyze a malfunctioning machine in a number of ways. For example, distinct fault clusters can be
10 generated from new fault log data from a malfunctioning locomotive and readily compared, manually or automatically, to weighted repair and distinct fault cluster combinations for prediction of one or more repairs as described in greater detail below.

15 As shown in FIG. 11, a process 150 of the present invention provides updating directed weight data storage unit 26 to include one or more new cases. For example, a new repair and fault log data 25 (FIG. 1) from a malfunctioning locomotive is received at 152. At 154, a plurality of repair and distinct fault cluster combinations for the plurality of the distinct
20 fault is generated.

The number of times each fault cluster occurred for related repairs is updated at 155, and the number of times each fault cluster occurred for all repairs are updated at 156. Thereafter, the weighted repair and distinct fault cluster combinations are redetermined at 158.

25 As noted above, the system provides prediction of repairs from fault log data from a malfunctioning machine. Desirably, after verification of the repair(s) for correcting a malfunction the new case can be inputted and updated into the system.

From the present invention, it will be appreciated by those skilled in the art that the repair and fault cluster combinations may be generated and stored in memory when generating the weights therefor, or alternatively, be stored in either the case data storage unit, directed weight storage unit, or a separate data storage unit.

Processor 12 is also operable to receive new fault log data 200 for analysis thereof. FIG. 2 shows in greater detail an exemplary portion 220 of the new fault log data 200 which may include a customer identification number 222, a locomotive identification number or unit 224, the dates 225 the faults occurred, the fault codes 226, and a fault code description 228. Additional information may also include various sensor readings, e.g., temperature sensor readings, pressure sensor readings, electrical sensor readings, engine power readings, etc. Desirably, the new fault log data includes faults occurring over a predetermined period of time prior such as a predetermined number of days (e.g., 14 days). It will be appreciated that other suitable time periods may be chosen. Advantageously, as explained below, the period of time corresponds to the period of time used for predetermining weighted repair and distinct fault cluster combinations.

FIG. 13 is a flowchart which generally describes the steps for analyzing new fault log data 200 (FIG. 1). As shown in FIG. 13 at 232, the new fault log data comprising a plurality of faults from a malfunctioning machine is received. At 233, a plurality of distinct faults from the new fault log data is identified, and at 234, the number of times each distinct fault occurred in the new fault log data is determined. As used herein, the term "distinct fault" is a fault or a fault code which differs from other faults or fault codes so that, as described in greater detail below, if a portion of the fault log data includes more than one occurrence of the same fault or fault code, the similar faults or fault codes are identified only once. As will become apparent from the discussion below, it is the selection of

distinct faults which is important and not the order or sequence of their arrangement in the fault log data.

FIG. 14 shows the plurality of distinct faults and the number of times in which each distinct fault occurred for fault log 220 (FIG. 12). In this example, fault code 7311 represents a phase module malfunction which occurred 24 times, fault code 728F indicates an inverter propulsion malfunction which occurred twice, fault code 76D5 indicates a fault reset which occurred once, and fault code 720F indicates an inverter propulsion malfunction which occurred once.

With reference again to FIG. 13, a plurality of fault clusters is generated for the distinct faults at 236. FIGS. 15A-15D illustrate the distinct fault clusters generated from the distinct faults extracted from fault log data 200. Four single fault clusters (e.g., fault code 7311, fault code 728F, fault code 76D5, and fault code 720F) are illustrated in FIG. 15A. Six double fault clusters (e.g., fault codes 76D5 and 7311, fault codes 76D5 and 728F, fault codes 76D5 and 720F, fault codes 7311 and 728F, fault codes 7311 and 720F, and fault codes 728F and 720F) are illustrated in FIG. 15B. Four triple fault clusters (e.g., fault codes 76D5, 7311, and 728F), fault codes 76D5, 7311, and 720F, fault codes 76D5, 728F, and 720F, and fault codes 7311, 728F, and 720F) are illustrated in FIG. 15C, and one quadruple fault cluster (e.g., 76D5, 7311, 728F, and 720F) is illustrated in FIG. 15D.

From the present description, it will be appreciated by those skilled in the art that a fault log having a greater number of distinct faults would result in a greater number of distinct fault clusters (e.g., ones, twos, threes, fours, fives, etc.).

At 238, at least one repair is predicted for the plurality of fault clusters using a plurality of predetermined weighted repair and fault cluster combinations. The plurality of predetermined weighted repair and fault cluster combinations may be generated as follows.

With reference again to FIG. 1, processor 12 is desirably operable to process historical repair data contained in a repair data storage unit 20 and historical fault log data contained in a fault log data storage unit 22 regarding one or more locomotives.

5 For example, repair data storage unit 20 includes repair data or records regarding a plurality of related and unrelated repairs for one or more locomotives. Fault log data storage unit 22 includes fault log data or records regarding a plurality of faults occurring for one or more locomotives.

10 FIG. 16 illustrates a printout 250 of the results generated by system 10 (FIG. 1) for fault log 200 (FIG. 1), in which in a top portion 252, a plurality of corresponding repairs 253, assigned weights 254, and fault clusters 255 are presented. As shown in a bottom portion 260 of printout 250, five recommendations for likely repairs actions are presented for
15 review by a field engineer.

 FIG. 17 is a flowchart of an exemplary process 300 for determining and presenting the top most likely repair candidates which may include repairs derived from predetermined weighted repair and distinct fault cluster combinations having the greatest assigned weighted values or
20 repairs which are determined by adding together the assigned weighted values for fault clusters for related repairs.

 As shown in FIG. 17, initially, a distinct fault cluster generated from the new fault log data is selected at 302. At 304, predetermined repair(s) and assigned weight(s) corresponding to the
25 distinct fault cluster are selected from directed weight storage unit 26 (FIG. 1).

At 306, if the assigned weight for the predetermined weighted repair and fault cluster combination is determined by a plurality of cases for related and unrelated repairs which number less than a predetermined number, e.g., 5, the fault cluster is excluded and the next distinct fault cluster is selected at 302. This prevents weighted repair and fault cluster combinations which are determined from only a few cases from having the same effect in the prediction of repairs as weighted repair and fault cluster combinations determined from many cases.

If the number of cases is greater than the predetermined minimum number of cases, at 308, a determination is made as to whether the assigned value is greater than a threshold value, e.g., 0.70 or 70%. If so, the repair is displayed at 310. If the fault cluster is not the last fault cluster to be analyzed at 322, the next distinct fault cluster is selected at 302 and the process is repeated.

If the assigned weight for the predetermined weighted repair and fault cluster combination is less than the predetermined threshold value, the assigned weights for related repairs are added together at 320. Desirably, up to a maximum number of assigned weights, e.g., 5, are used and added together. After selecting and analyzing the distinct fault clusters generated from the new fault log data, the repairs having the highest added assigned weights for fault clusters for related repairs are displayed at 324.

With reference again to FIG. 16, repairs corresponding to the weighted repair and fault cluster combinations in which the assigned weights are greater than the threshold value are presented first. As shown in FIG. 16, repair codes 1766 and 1777 and distinct fault cluster combinations 7311, 728F, and 720F, have an assigned weight of 85% and indicate a recommended replacement of the EFI.

As also shown in FIG. 16, repairs for various fault clusters having the highest added or total weight are presented next. For example, repair code 1677 which corresponds to a traction problem has a totaled assigned weight of 1.031, repair code 1745 which corresponds to a locomotive software problem has a totaled assigned weight of 0.943, and repair code 2323 which corresponds to an overheated engine has a totaled assigned weight of 0.591.

Advantageously, the top five most likely repair actions are determined and presented for review by a field engineer. For example, up to five repairs having the greatest assigned weights over the threshold value are presented. When there is less than five repairs which satisfy the threshold, the remainder of recommended repairs are presented based on a total assigned weight.

Desirably the new fault log data is initially compared to a prior fault log data from the malfunctioning locomotive. This allows determination whether there is a change in the fault log data over time. For example, if there is no change, e.g., no new faults, then it may not be necessary to process the new fault log data further.

FIG. 18 illustrates a flowchart of an exemplary automated process 500 for analyzing fault log data from a locomotive, e.g., new fault log data which is generated every day, using system 10. In particular, process 500 accommodates the situation where a prior repair is undertaken or a prior repair is recommended within the predetermined period of time over which the fault log data is analyzed. This avoids recommending the same repair which has been previously recommended and/or repaired.

At 502, new fault log data is received which includes faults occurring over a predetermined period of time, e.g., 14 days. The fault log data is analyzed, for example as described above, generating distinct fault clusters and comparing the generated fault clusters to predetermined weighted repair and fault cluster combinations.

At 504, the analysis process may use a thresholding process described above to determine whether any repairs are recommended (e.g., having a weighted value over 70%). If no repairs are recommended, the process is ended at 506. The process is desirably repeated again with a
5 download of new fault log data the next day.

If a repair recommendation is made, existing closed (e.g., performed or completed repairs) or prior recommended repairs which have occurred within the predetermined period of time are determined at 508. For example, existing closed or prior recommended repairs may be stored
10 and retrieved from repair data storage unit 20. If there are no existing or recommended repairs than all the recommended repairs at 504 are listed in a repair list at 700.

If there are existing closed or prior recommended repairs, then at 600, any repairs not in the existing closed or prior recommended
15 repairs are listed in the repair list at 700.

For repairs which are in the existing closed or prior recommended repairs, at 602, the look-back period (e.g., the number of days over which the faults are chosen) is revised. Using the modified look-back or shortened period of time, the modified fault log data is analyzed at
20 604, as described above, using distinct fault clusters, and comparing the generated fault clusters to predetermined weighted repair and fault cluster combinations.

At 606, the analysis process may use the thresholding process described above to determine whether any repairs are
25 recommended (e.g., having a weighted value over 70%). If no repairs are recommended, the process is ended at 608 until the process is stated again with a new fault log data from the next day, or if a repair is recommended it is added to the repair list at 700.

From the present description, it will be appreciated by those skilled in the art that other processes and methods, e.g., different thresholding values or fault log data analysis which does not use distinct fault clusters, may be employed in predicting repairs from the new fault log data according to process 500 which takes into account prior performed repairs or prior recommended repairs.

Thus, the present invention provides in one aspect a method and system for processing a new fault log which is not restricted to sequential occurrences of faults or error log entries. In another aspect, the calibration of the diagnostic significance of fault clusters is based upon cases of related repairs and cases for all the repairs.

Thus, the present invention provides in one aspect a method and system for automatically harvesting potentially valid diagnostic cases by interleaving repair and fault log data which is not restricted to sequential occurrences of faults or error log entries. In another aspect, standard diagnostic fault clusters can be generated in advance so they can be identified across all cases and their relative occurrence tracked. In still another aspect, the calibration of the significance of repair and distinct fault cluster combinations based upon cases of related repairs and cases for all the repairs is determined.

In addition, when initially setting up case data storage unit 24, a field engineer may review each of the plurality of cases to determine whether the distinct faults, and in particular, number of times the distinct faults occur, provide a good indication of the repair. If not, one or more cases can be excluded or removed from case data storage unit 24. This review by a field engineer would increase the initial accuracy of the system in assigning weights to the repair and fault cluster combinations.

While the invention has been described with reference to preferred embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In
5 addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiments disclosed herein, but that the invention will include all embodiments falling within the scope of the
10 appended claims.

WHAT IS CLAIMED IS:

1. A method for analyzing fault log data from a malfunctioning locomotive or other large land-based, self-powered transport equipment, comprising:
 - receiving new fault log data (232) comprising a plurality of
 - 5 faults from the malfunctioning equipment;
 - selecting a plurality of distinct faults (233) from the new fault log data;
 - generating at least one distinct fault cluster (236) from the plurality of distinct faults;
 - 10 generating a plurality of weighted repair and distinct fault cluster combinations; and
 - identifying at least one repair (238) for the at least one distinct fault cluster using the plurality of weighted repair and distinct fault cluster combinations.
- 15 2. The method of claim 1 wherein the at least one distinct fault cluster (236) comprises at least one of a single distinct fault and a plurality of distinct faults.
- 20 3. The method of claim 1 wherein each of the plurality of weighted repair and distinct fault cluster combinations are generated from a plurality of cases (60), each case comprising a repair and at least one distinct fault, and each of the plurality of weighted repair and distinct fault cluster combinations being assigned a weight determined by dividing (100) the number of times the combination occurs in cases comprising related
- 25 repairs by the total number of times the combination occurs in said plurality of cases.

4. The method of claim 3 wherein identifying the at least one repair comprises selecting at least one repair using the plurality of weighted repair and fault cluster combinations and adding assigned weights for distinct fault clusters for related repairs.

5 5. The method of claim 1 said generating a plurality of weighted repair and distinct fault cluster combinations (50, 100) utilizes a plurality of repairs and fault log data comprising a plurality of faults.

6. The method of claim 1 wherein the receiving fault
10 log data (232) comprises receiving a new fault log data and comparing the new fault log data to a prior fault log data.

7. A system for analyzing fault log data from a malfunctioning locomotive or other large land-based, self-powered
15 transport equipment, comprising:

a directed weight data storage unit (26) adapted to store a plurality of weighted repair and distinct fault cluster combinations;

a processor (12) adapted to receive new fault log data (232) comprising a plurality of faults from the malfunctioning equipment;

20 a processor (12) for selecting a plurality of distinct faults (233) from the new fault log data;

a processor (12) for generating at least one distinct fault cluster (236) from the selected plurality of distinct faults;

a processor (12) for generating a plurality of weighted repair
25 and distinct fault cluster combinations; and

a processor (12) for identifying at least one repair (238) for the at least one distinct fault cluster using the plurality of predetermined weighted repair and distinct fault cluster combinations.

8. The system of claim 7 wherein a single processor unit constitutes said processors.

9. A system of claim 7 further comprising:

5 a processor for generating a plurality of cases (52, 54, 56, 60) from the repair data and the fault log data, each case comprising a repair and a plurality of distinct faults;

a processor for generating, for each of the plurality of cases, at least one repair and distinct fault cluster combination (62); and

10 a processor for assigning, to each of the repair and distinct fault cluster combinations, a weight (100), whereby weighted repair and distinct fault cluster combinations facilitate identification of at least one repair for the malfunctioning equipment.

15 10. The system of claim 9 wherein the processor for generating the plurality of cases (52, 54, 56, 60) comprises a processor for selecting a repair from the repair data and selecting a plurality of distinct faults (54) from the fault log data over a period of time prior to the repair.

20 11. The system of claim 9 wherein the processor for assigning weights (100) comprises a processor for determining (102), for each repair and distinct fault cluster combination, a number of times the combination occurs in cases comprising related repairs, and a number of times the combination occurs in the plurality of cases.

25 12. The system of claim 11 wherein the processor for assigning a weight (100), for each repair and distinct fault cluster combination, comprises a processor for dividing (108) the number of times the combination occurs in cases comprising related repairs by the number of times the combination occurs in the plurality of cases.

13. The system of claim 11 further comprising:
a processor for generating a new case (152) from repair data and fault log data, the case comprising a repair and a plurality of distinct faults;
- 5 a processor for generating, for the new case, a plurality of fault clusters (154) for the plurality of distinct faults; and
a processor for redetermining a weight (155, 156, 158) for each of the plurality of repair and fault cluster combinations to include the new case.
- 10 14. The system of claim further comprising:
a repair log data storage unit (20) adapted to store a plurality of repairs; and
a fault log data storage unit (22) adapted to store a plurality of faults.

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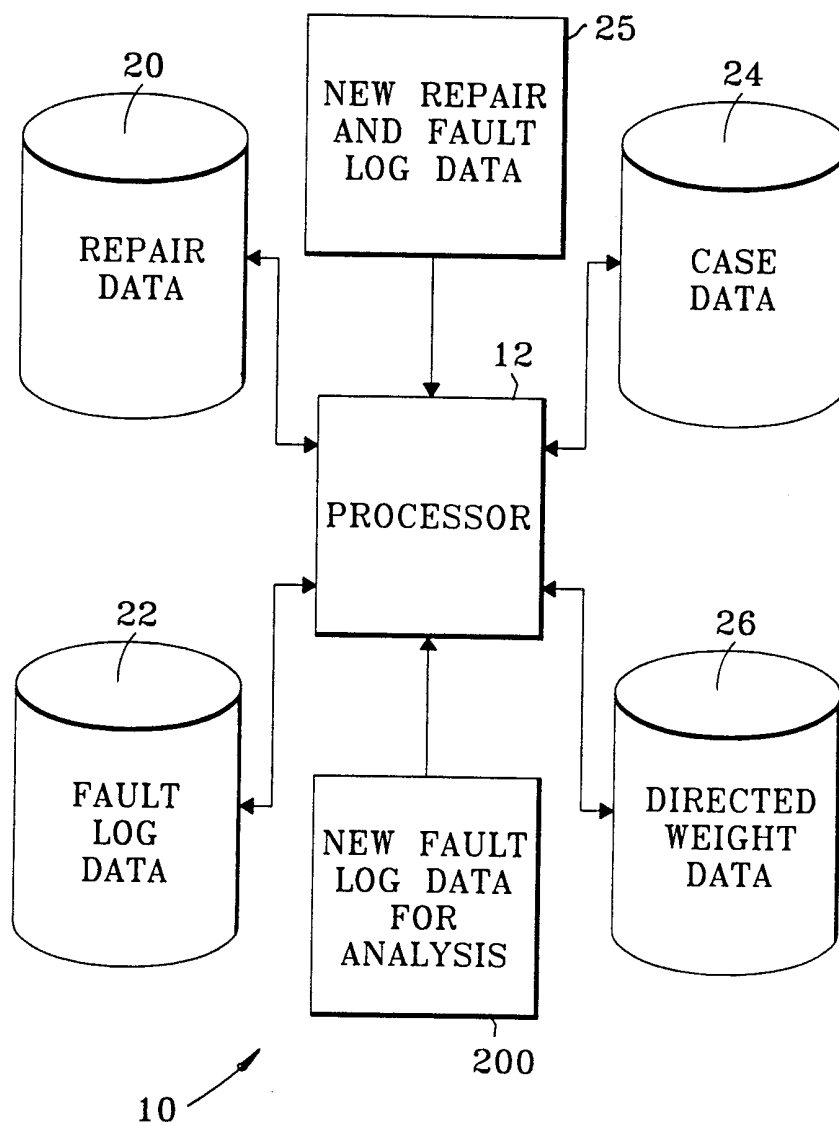
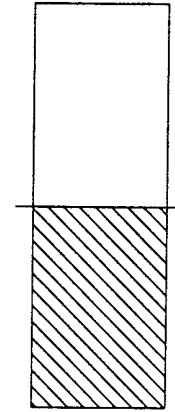


Fig. 1

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32		33	34		35	36		37	30
CUST	UNIT	DATE			CODE	DESC	DESC1		
RR	3500	Sun Jul 13 1997			1111	Piping Fittings-Engine Intercooler	REPAIRED WATER LEAK AT TOP OF RT		
RR	3500	Tue Jul 01 1997			2222	Lube Oil-Engine	WATER IN LUBE OIL CHANGED OIL		
RR	3500	Sat Jun 28 1997			3333	BRP-Battery Charger Regulator Panel	NO BATTCARGE-REPL BPR		
RR	3500	Wed Jun 18 1997			4444	EFI-High Pressure Pump	REPLACE 3 HP PUMPS NOT FOR FIRING		
RR	3500	Mon Jun 09 1997			5555	Turbocharger Assembly-General-Eng	TURBO DRAGSSECONDARY DAMAGE-RPL		
RR	3500	Sat May 24 1997			6666	Cylinder Assembly General-Eng	REPL R6 PA FOR SECONDARY DAMAGE		
RR	3500	Sat May 24 1997			7777	Cylinder Assembly General-Eng	TRIPPING COP PISTON FAILURE CO		

Fig. 2A



30 ↗

FAILMODE_DESC	SUB_ASSEMBLY_CODE	MAIN_ASSEMBLY_CODE
LEAKING FLUIDAIR	ENGINTCOOL	ENGINE
CONTAMINATED	LUBEOIL	ENGISUPT
UNKNOWNUNDETERMINED	POWERPANEL	POWERELN
UNKNOWNUNDETERMINED	ENGFUELINJ	ENGINE
UNKNOWNUNDETERMINED	ENGTURBO	ENGINE
UNKNOWNUNDETERMINED	POWERASSY	ENGINE
UNKNOWNUNDETERMINED	POWERASSY	ENGINE

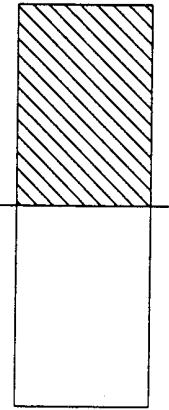


Fig. 2B

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42	44	45	46	40	RR	3500	03-may-1997	1000	90623.06	90637.20	0.0CS	0
					RR	3500	03-may-1997	2000	90623.06	90637.20	0.0CS	0
					RR	3500	22-may-1997	3000	91067.93	91067.93	11.4 F	5
					RR	3500	22-may-1997	4000	91067.93	91067.93	11.4 F	5
					RR	3500	22-may-1997	5000	91068.70	91068.71	16.5 F	4
					RR	3500	22-may-1997	6000	91068.70	91068.71	16.5 F	4
					RR	3500	22-may-1997	7000	91068.71	0.00	17.9 F	1
					RR	3500	22-may-1997	8000	91068.71	0.00	17.9 F	1
					RR	3500	22-may-1997	9000	91069.55	91069.55	23.1 F	5
					RR	3500	22-may-1997	1111	91069.55	91069.55	23.1 F	5
					RR	3500	22-may-1997	2222	91069.56	91069.58	27.4 F	6

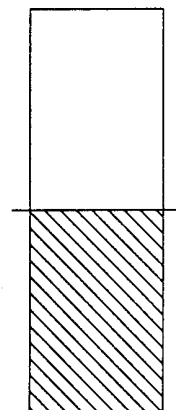


Fig. 3A

40

48

0	1	2	0	101	97	R	E	0	0	_____	Intake	Manifold	Air	Too
0	1	2	0	101	97	R	E	0	0	_____	Intake	Manifold	Air	Too
992	288	4706	202	177	182	M	E	F	0	6AB_M_S_	COP	Trip		
992	288	4706	202	177	182	M	E	F	0	6AB_M_S_	COP	Trip		
885	338	2864	133	175	186	M	E	2	4	6AB_M_S_	COP	Trip		
885	338	2864	133	175	186	M	E	2	4	6AB_M_S_	COP	Trip		
458	6	0	0	174	186	R	E	F	4	EAB_____	Fault	Reset	While in Lc	
458	6	0	0	174	186	R	E	F	4	EAB_____	Fault	Reset	While in Lc	
992	474	3005	148	180	187	M	E	2	0	R 6AB_M_S_	COP	Trip		
992	474	3005	148	180	187	M	E	2	0	R 6AB_M_S_	COP	Trip		
1010	506	2405	128	179	189	M	E	F	4	6AB_M_S_	COP	Trip		

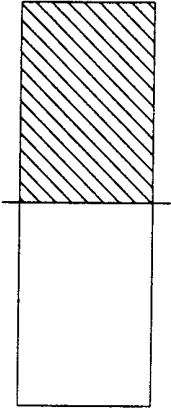


Fig. 3B

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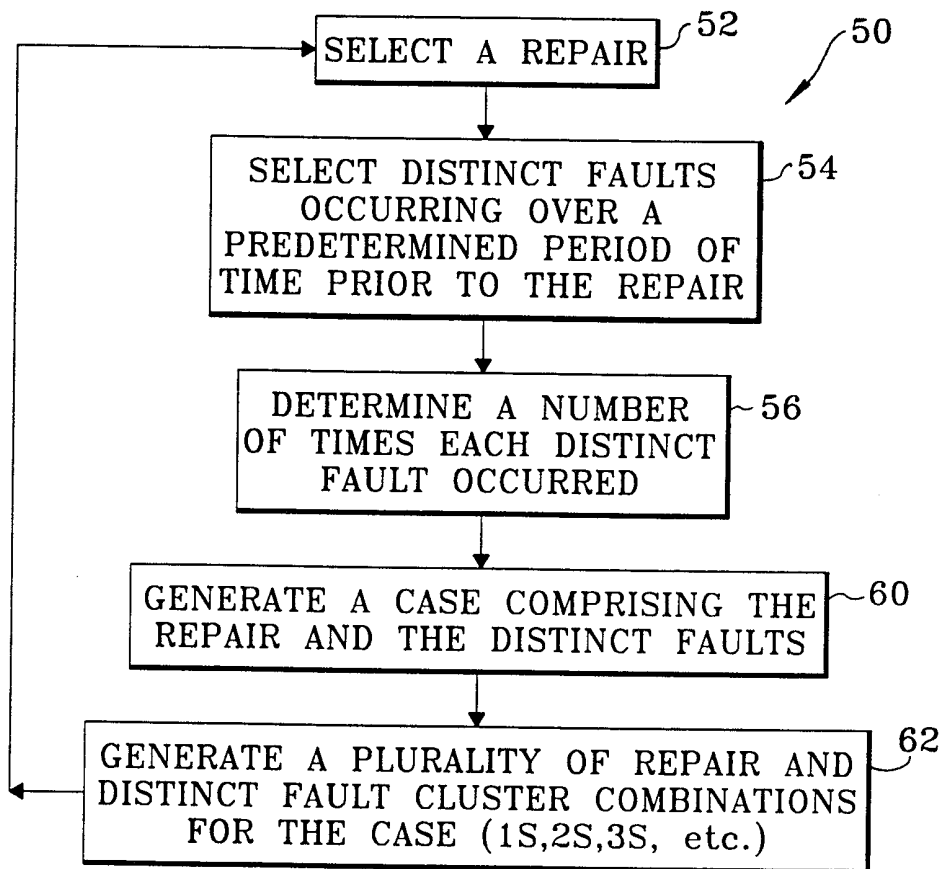


Fig. 4

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Fig. 5

		76		78		70	
72	RR_3500	31-DEC-1997_2322-SIGNATURES					
74	RR 3500	17-DEC-1997-DEC-1997 3		80			
82	7A5D	3	20.4444	8	175	01	1112 2100.66
	7A4D	2	0	1	168	170	1 0
	76D5	1	31.20000	8	176	203	1398 1866
84		86					
DID NOT		FIRE ON POP TEST					

Fig. 6A

RR_3500	31-DEC-1997_2322-SIGNATURES_ONES
7A5D	
7A4A	
76D5	

Fig. 6B

RR_3500	31-DEC-1997_2322-SIGNATURES_TWOS
7A5D 7A4A	
7A4A 76D5	
7A4A 76D5	

Fig. 6C

RR_3500	31-DEC-1997_2322-SIGNATURES_THREES
7A5D 7A4A 76D5	

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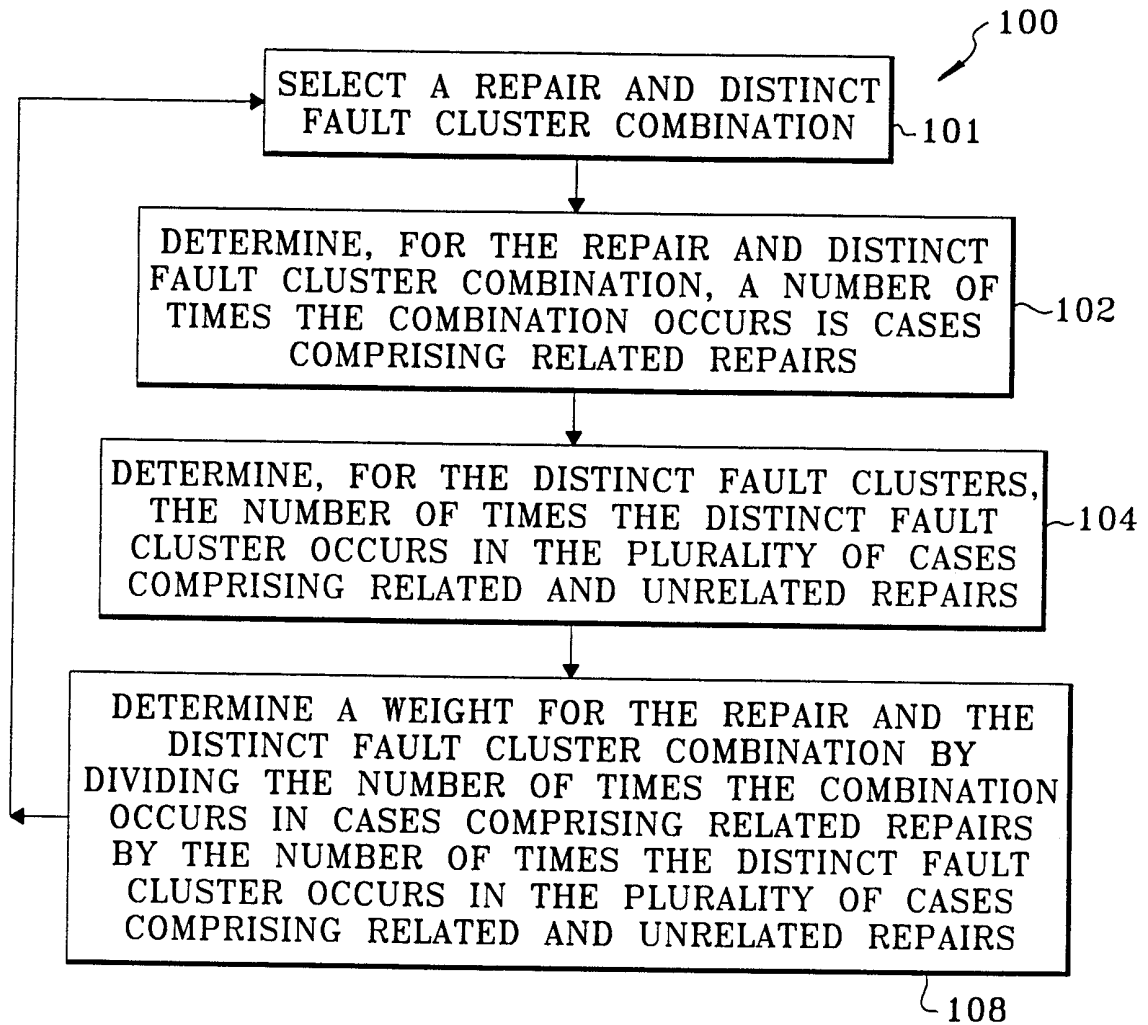


Fig. 7

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Fig. 8A

110

2322_ONES

778A 1
 7C89 1
 7150 4
 7A4A 1
 7151 1
 7313 1
 7A4C 1
 7152 1
 7153 2
 7154 5
 7390 1
 73A3 3
 7C18 2
 7C91 3
 7C92 1
 7C94 1
 73AC 1
 7080 2
 7404 1
 7405 2
 7081 1
 7325 3
 7A5D 23
 7082 2
 7083 2
 7407 1
 7084 1
 7085 1
 7086 1
 7484 1
 7485 2
 7487 1
 7A62 3
 7A63 1
 7A67 1
 76D5 24
 7A68 1
 748F 2
 7013 1
 •
 •
 •

Fig. 8B

112

2322_TWOS

7A5D 76D5 20
 7A5D 7A4A 1
 7A4A 76D5 1
 •
 •
 •

Fig. 8C

114

2322_THREES

7A5D 7A4A 76D5 1
 •
 •
 •

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120 Fig. 9A

ALL_ONES

7A58 1
 7A59 6
 7A4A 4
 CA17 3
 7320 2
 7401 13
 CA18 2
 7402 12
 73AB 17
 7403 1
 73AC 23
 7322 7
 7404 21
 7323 12
 7080 50
 7324 2
 7405 33
 7081 23
 7325 16
 7406 1
 7082 23
 7A5D 84
 7326 2
 7164 1
 7A5E 1
 7407 23
 7083 25
 C75D 2
 7A5F 1
 7084 26
 7085 29
 7329 2
 76D5 24
 7089 3
 7A60 2
 .
 .
 .

Fig. 9B

ALL_TWOS

7A5D 76D5 73
 7A5D 7A4A 1
 7A4A 76D5 4
 .
 .
 .

Fig. 9C

ALL_THREES

7A5D 7A4A 76D5 1
 .
 .
 .

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Fig. 10A

130

7405	2302	0.090
7405	2142	0.090
7405	2423	0.030
7405	1742	0.030
7405	1745	0.090
7A5D	2320	0.107
7A5D	2322	0.273
7A5D	2323	0.261
7A5D	2206	0.047
7A5D	2129	0.023
7A5D	1716	0.011
740F	1745	0.080
740F	1783	0.016
740F	1867	0.032
740F	1868	0.016
740F	1869	0.080
740F	1788	0.016
76D5	2320	0.029
76D5	2007	0.022
76D5	2322	0.089
76D5	2323	0.160
76D5	2206	0.089
76D5	2129	0.022
76D5	1715	0.003
76D5	1716	0.007
7A4A	2322	0.250

•
•
•

140

Fig. 10B

7A5D	76D5	2320	0.095
7A5D	76D5	2322	0.273
7A5D	76D5	2323	0.287
7A5D	76D5	2206	0.054
7A5D	76D5	2129	0.027
7A5D	76D5	1716	0.013
7A5D	76D5	2329	0.109
7A5D	76D5	1678	0.013
7A5D	76D5	2333	0.041
7A5D	76D5	1681	0.013
7A5D	76D5	1501	0.013
7A5D	76D5	2151	0.013
7A5D	76D5	1742	0.013
7A5D	76D5	1707	0.027
7A5D	7A4A	2322	1.000
7A4A	76D5	2322	0.250

•
•
•

145

Fig. 10C

7A5D	7A4A	76D5	2322	1.000
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•
•
•

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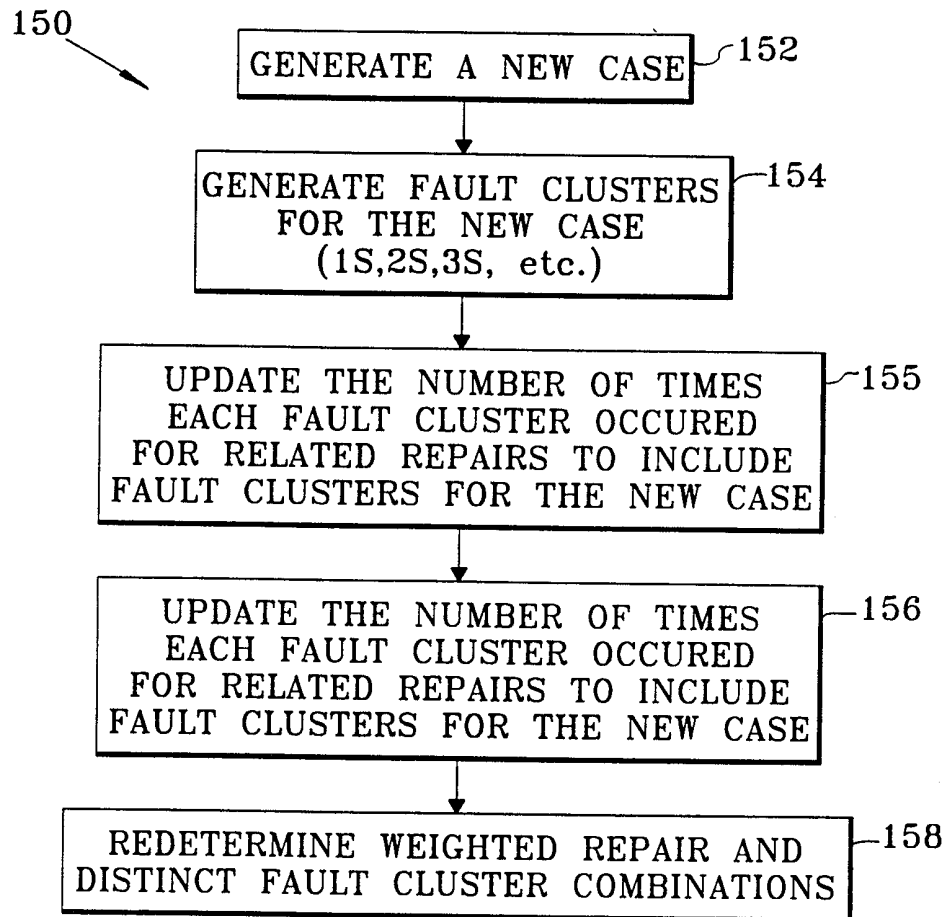


Fig. 11

Fig. 12A

222		224		220	
CUST FLEET	RN	DWNLD DATE	TIME	HOURS	#FLTS
RR	1550	12/17/1998	05:49	104837.82	28

225

226

OCCUR DATE	FAULT CODE	OCCUR HOURS	RESET HOURS	LOCO SPED	CC TH	ENG SPED	VOLT
DEC-15	1111-01	104791.4	104791.4	0.1	F1	439	300
DEC-15	2222-01	104791.4	104791.4	0.1	F1	436	299
DEC-15	3333-	104791.4	0.0	4.0	F1	436	399
DEC-15	4444-04	104791.4	104791.4	4.9	F1	436	400
DEC-15	5555-0C	104803.4	104803.5	0.0	F1	577	4
DEC-16	6666-0C	104814.4	104814.5	0.0	F1	577	3
DEC-16	7777-02	104814.4	104814.4	0.0	F1	577	3
DEC-16	8888-04	104814.5	104817.0	0.0	F1	565	414

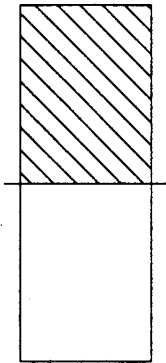


Fig. 12B

228

MAIN AMPS	ALT FLD	WAT TMP	OIL TMP	L	L	FAULT DESCRIPTION
79		168	189	M		PM3A+OR IMC2-3,4,7 BAD
64		168	189	M		PM3A+OR IMC2-3,4,7 BAD
362		168	188	M		FAULT RESET WHILE IN LEV
281		168	188	M		PM3A+OR IMC2-3,4,7 BAD
1		163	168	R		INV1 PROPULSION SYSTEM FAULT
0		168	170	R		INV2 PROPULSION SYSTEM FAULT
0		168	170	R		PM3A+OR IMC2-3,4,7 BAD
3		168	170	M		PM3A+OR IMC2-3,4,7 BAD

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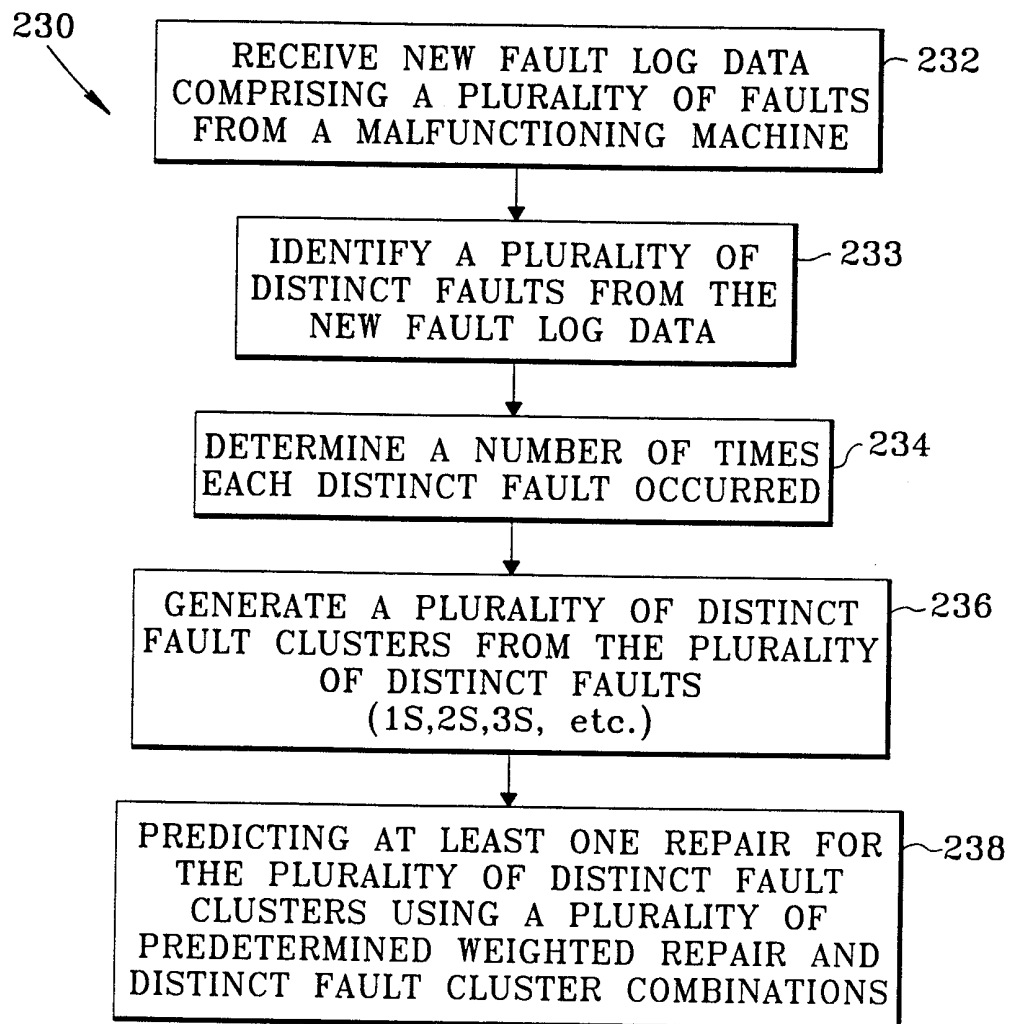


Fig. 13

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Fig. 14

7311	24
728F	2
76D5	1
720F	1

Fig. 15A

7311
728F
76D5
720F

Fig. 15B

76D5	7311
76D5	728F
76D5	720F
7311	728F
7311	720F
728F	720F

Fig. 15C

76D5	7311	728F
76D5	7311	720F
76D5	728F	720F
7311	728F	720F

Fig. 15D

76D5	7311	728F	720F
------	------	------	------

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250 ↗

252 ↗	253 ↗	254 ↗	253 ↗	255 ↗
ENTERED	1777	WITH	0.850	BASED ON 1777 7311 728F 720F
ENTERED	1766	WITH	0.850	BASED ON 1766 7311 728F 720F
ENTERED	1715	WITH	0.364	BASED ON 1715 76D5 7311
ENTERED	1677	WITH	0.300	BASED ON 1677 7311 720F
STORING	1777	WITH	0.300	BASED ON 1777 7311 720F
STORING	1766	WITH	0.300	BASED ON 1766 7311 720F
STORING	1777	WITH	0.300	BASED ON 1777 7311 728F
STORING	1677	WITH	0.300	BASED ON 1677 7311 728F
STORING	1766	WITH	0.300	BASED ON 1766 7311 728F
ENTERED	1745	WITH	0.280	BASED ON 1745 76D5 728F 720F
ENTERED	2323	WITH	0.273	BASED ON 2323 76D5 7311
STORING	1677	WITH	0.273	BASED ON 1677 76D5 7311
STORING	1715	WITH	0.211	BASED ON 1715 7311
STORING	1745	WITH	0.200	BASED ON 1745 76D5 728F
STORING	1745	WITH	0.184	BASED ON 1745 76D5 720F
STORING	2323	WITH	0.160	BASED ON 2323 76D5
STORING	1677	WITH	0.158	BASED ON 1677 7311
STORING	1777	WITH	0.158	BASED ON 1777 7311
STORING	1766	WITH	0.158	BASED ON 1766 7311
STORING	2323	WITH	0.158	BASED ON 2323 7311
STORING	1745	WITH	0.148	BASED ON 1745 728F 720F
ENTERED	1869	WITH	0.143	BASED ON 1869 7311 728F 720F
STORING	1745	WITH	0.130	BASED ON 1745 728F
ENTERED	2142	WITH	0.130	BASED ON 2142 728F 720F
STORING	1869	WITH	0.120	BASED ON 1869 76D5 728F 720F
ENTERED	1814	WITH	0.105	BASED ON 1814 7311
STORING	2142	WITH	0.103	BASED ON 2142 720F
STORING	2142	WITH	0.101	BASED ON 2142 728F

260 ↗

NUMBER OF DISTINCT FAULTS IN CURRENT CASE IS: 4

1766-	EFI	MATCHES	0.850
1777-	PRESSURE PUMP	MATCHES	0.850
1677-	TRACTION PROBLEM	MATCHES	1.031 CASES:32
1745-	LOCOMOTIVE SOFTWARE PROBLEMS	MATCHES	0.943 CASES:39
2323-	ENGINE OVER HEATED	MATCHES	0.591 CASES:71

Fig. 16

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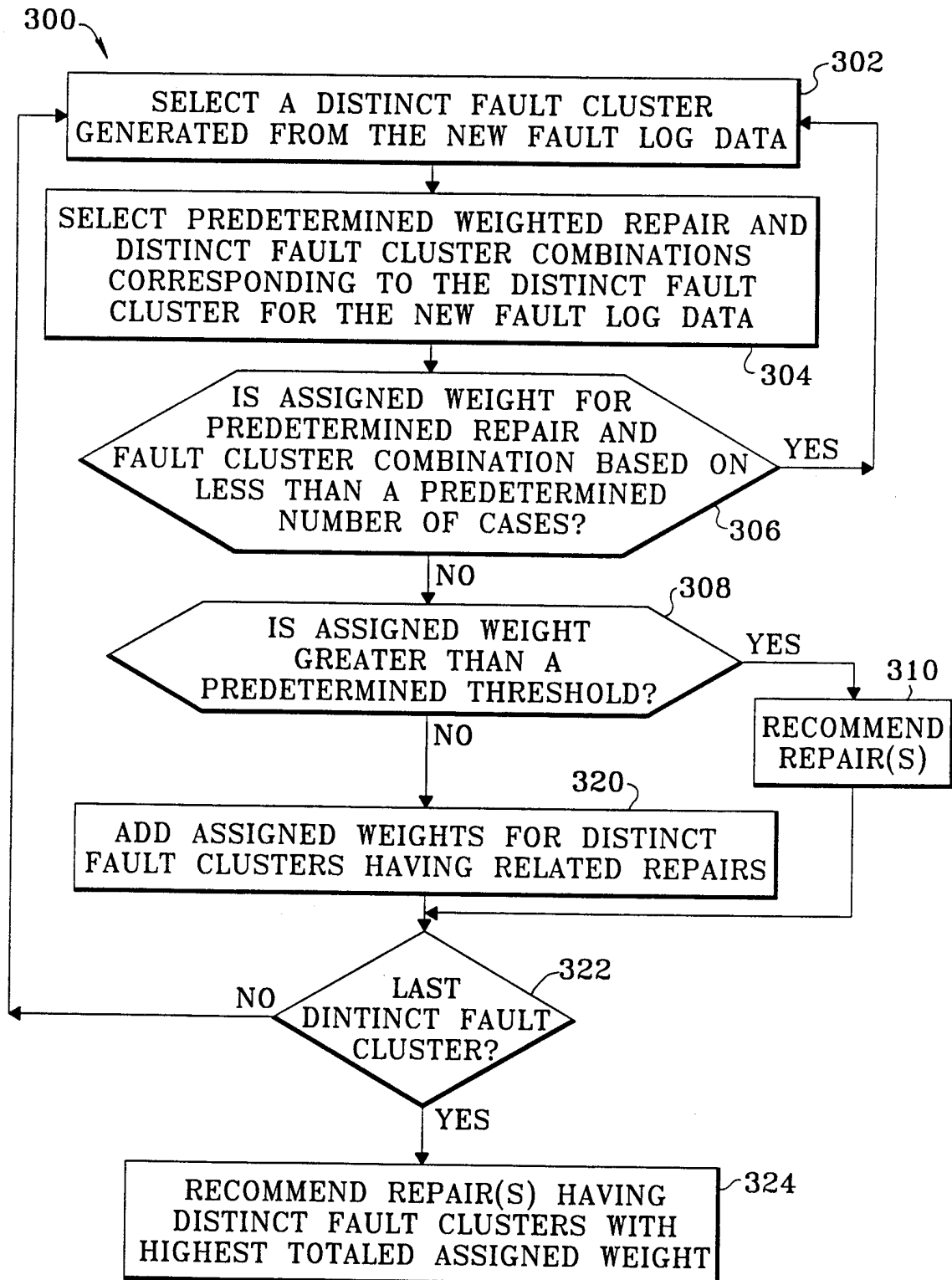


Fig. 17

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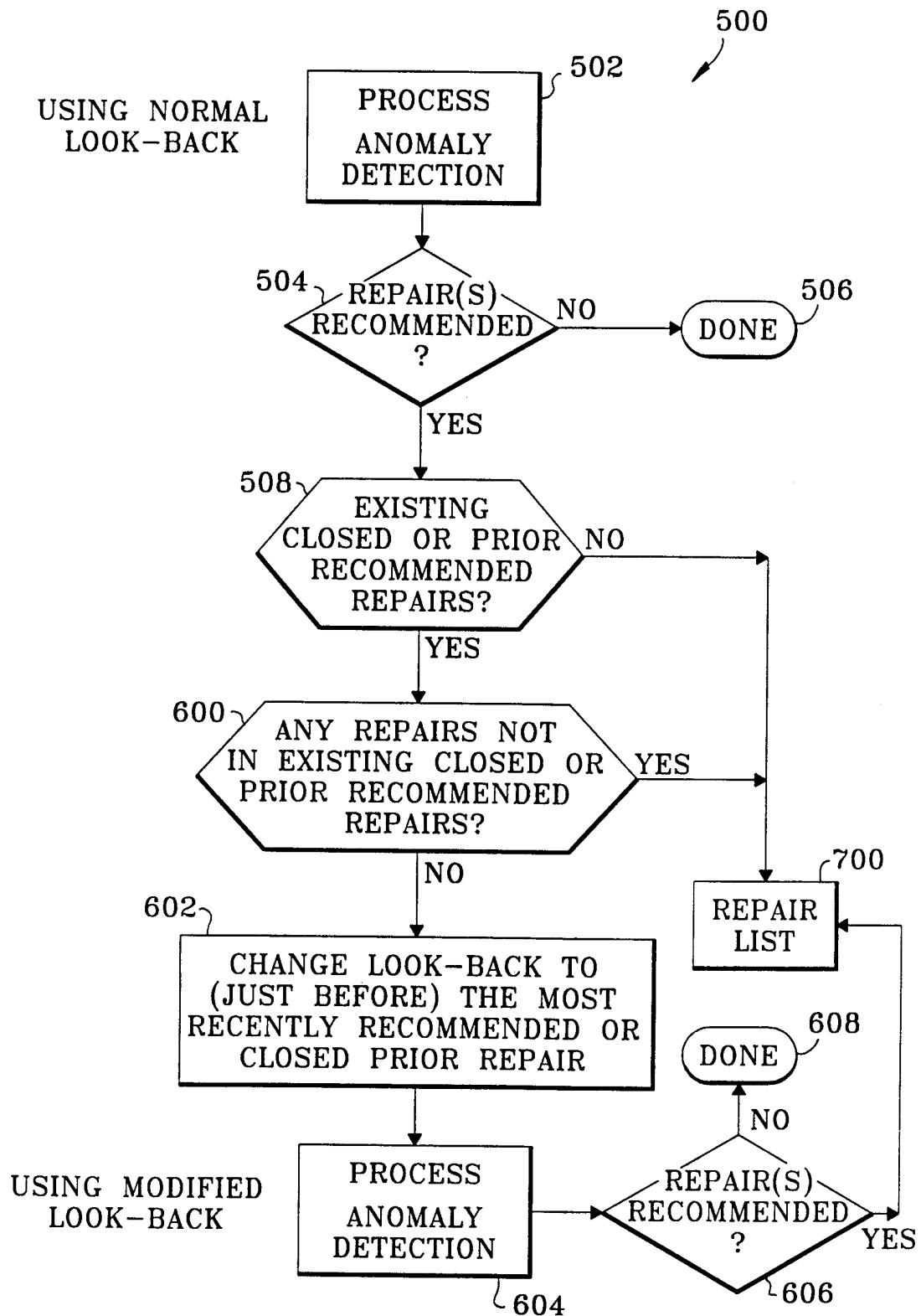


Fig. 18

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 00/08662

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G06F11/25

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 G06F

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 631 831 A (BIRD JOHN A ET AL) 20 May 1997 (1997-05-20) abstract; claims 1-6 ---	1-14
A	US 5 414 645 A (HIRANO SEIYO) 9 May 1995 (1995-05-09) abstract; claims 1-4; figure 12 ---	1-14
A	US 5 333 240 A (KATAYAMA YASUNORI ET AL) 26 July 1994 (1994-07-26) abstract -----	1-14

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

16 June 2000

Date of mailing of the international search report

26/06/2000

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 00/08662

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
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			JP 5116601 A	14-05-1993
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			JP 2272326 A	07-11-1990
			JP 6092914 B	16-11-1994
			DE 4012278 A	18-10-1990