US009270518B2

(12) **United States Patent**
Muro et al.

(10) **Patent No.: US 9,270,518 B2**
(45) **Date of Patent: Feb. 23, 2016**

(54) **COMPUTER SYSTEM AND RULE GENERATION METHOD**

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(73) Assignee: **Hitachi, Ltd.**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 496 days.

(21) Appl. No.: **13/698,163**

(22) PCT Filed: **Feb. 21, 2011**

(86) PCT No.: **PCT/JP2011/053688**
§ 371 (c)(1), (2), (4) Date: **Jan. 25, 2013**

(87) PCT Pub. No.: **WO2011/145374**
PCT Pub. Date: **Nov. 24, 2011**

(65) **Prior Publication Data**

US 2013/0205014 A1 Aug. 8, 2013

(30) **Foreign Application Priority Data**

May 17, 2010 (JP) 2010-113175

(51) **Int. Cl.**
H04L 29/06 (2006.01)
G06Q 10/06 (2012.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04L 29/06891*** (2013.01); ***G05B 23/0237*** (2013.01); ***G06Q 10/06*** (2013.01); ***H04L 67/12*** (2013.01)

(58) **Field of Classification Search**
CPC H04L 43/04; H04L 43/08; H04L 43/10; H04L 29/06891; H04L 67/12; G05B 23/0237; G06Q 10/06
USPC 340/500–539.32
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,792,389 B1 * 9/2004 Allen et al. 702/183
7,412,839 B2 * 8/2008 Jayanth 62/129
(Continued)

FOREIGN PATENT DOCUMENTS

JP 5-165888 7/1993
JP 8-189846 7/1996
(Continued)

OTHER PUBLICATIONS

Wakimoto, Koji; A Similarity Retrieval Method of Drawings Based on Graph Representation; Transactions of the Institute of Electronics, Information and Communication Engineers, Jul. 25, 1997; vol. J77-D-ll, No. 7; pp. 1302-1310.

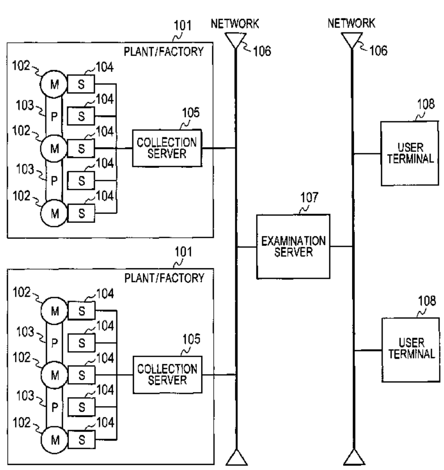
(Continued)

Primary Examiner — Dustin Nguyen
Assistant Examiner — Javier O Guzman
(74) *Attorney, Agent, or Firm* — Foley & Lardner LLP

(57) **ABSTRACT**

Disclosed is a computer system provided with a plurality of sensors provided in a plurality of devices to observe a predetermined amount, and a server for examining the physical amount transmitted from the sensors, wherein the plurality of devices are classified into a first device group and a plurality of second device groups, a plurality of second examination rules indicating the examination methods of the physical amount are set in the plurality of second device groups, the server calculates the similarity between the first device group and each of the second device groups, and, on the basis of the calculated similarity, a first examination rule to be set in the first device group is extracted from the plurality of second examination rules set in the plurality of second device groups.

14 Claims, 25 Drawing Sheets



(51) **Int. Cl.**
H04L 29/08 (2006.01)
G05B 23/02 (2006.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

2003/0120969	A1	6/2003	Saito	
2004/0199300	A1*	10/2004	Gustafsson et al.	701/1
2009/0046762	A1*	2/2009	Henshaw et al.	374/179
2012/0330931	A1*	12/2012	Nakano et al.	707/722

FOREIGN PATENT DOCUMENTS

JP	2007-094538	A	4/2007
JP	2011-221799	A	11/2011
WO	WO 03/055145	A1	7/2003

OTHER PUBLICATIONS

PCT International Search Report and Written Opinion on application PCT/JP2011/053688 mailed Mar. 15, 2011; 1 page.

* cited by examiner

FIG. 1

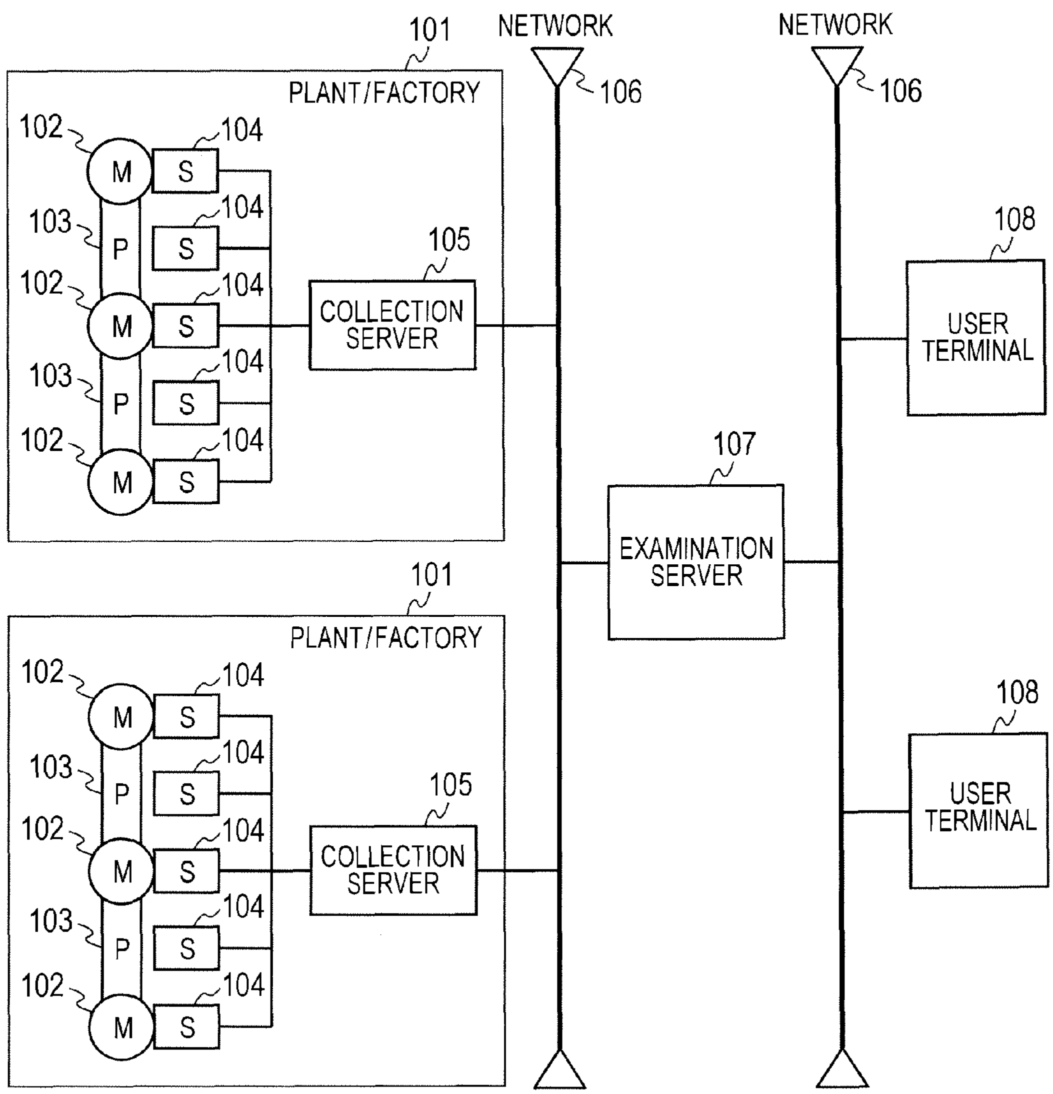

101
PLANT/FACTORY
102
103
104
M
P
S
105
COLLECTION SERVER
NETWORK
106
107
EXAMINATION SERVER
108
USER TERMINAL

FIG. 2

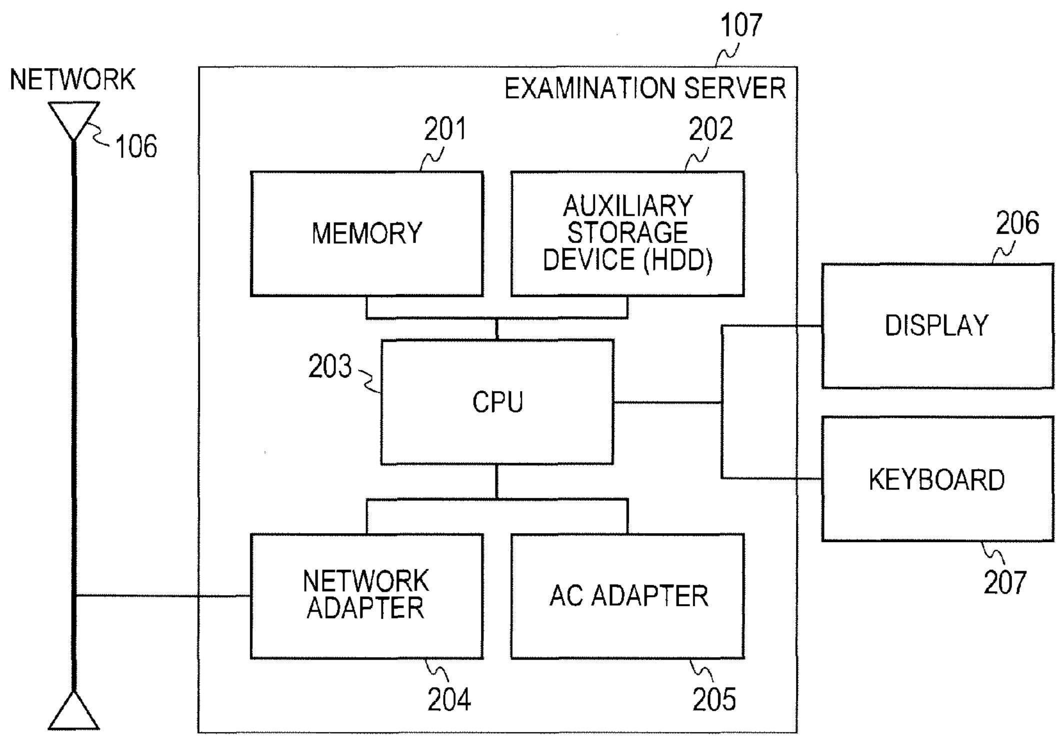

107
EXAMINATION SERVER
NETWORK
106
201
202
MEMORY
AUXILIARY STORAGE DEVICE (HDD)
206
DISPLAY
203
CPU
KEYBOARD
207
NETWORK ADAPTER
AC ADAPTER
204
205

FIG. 3

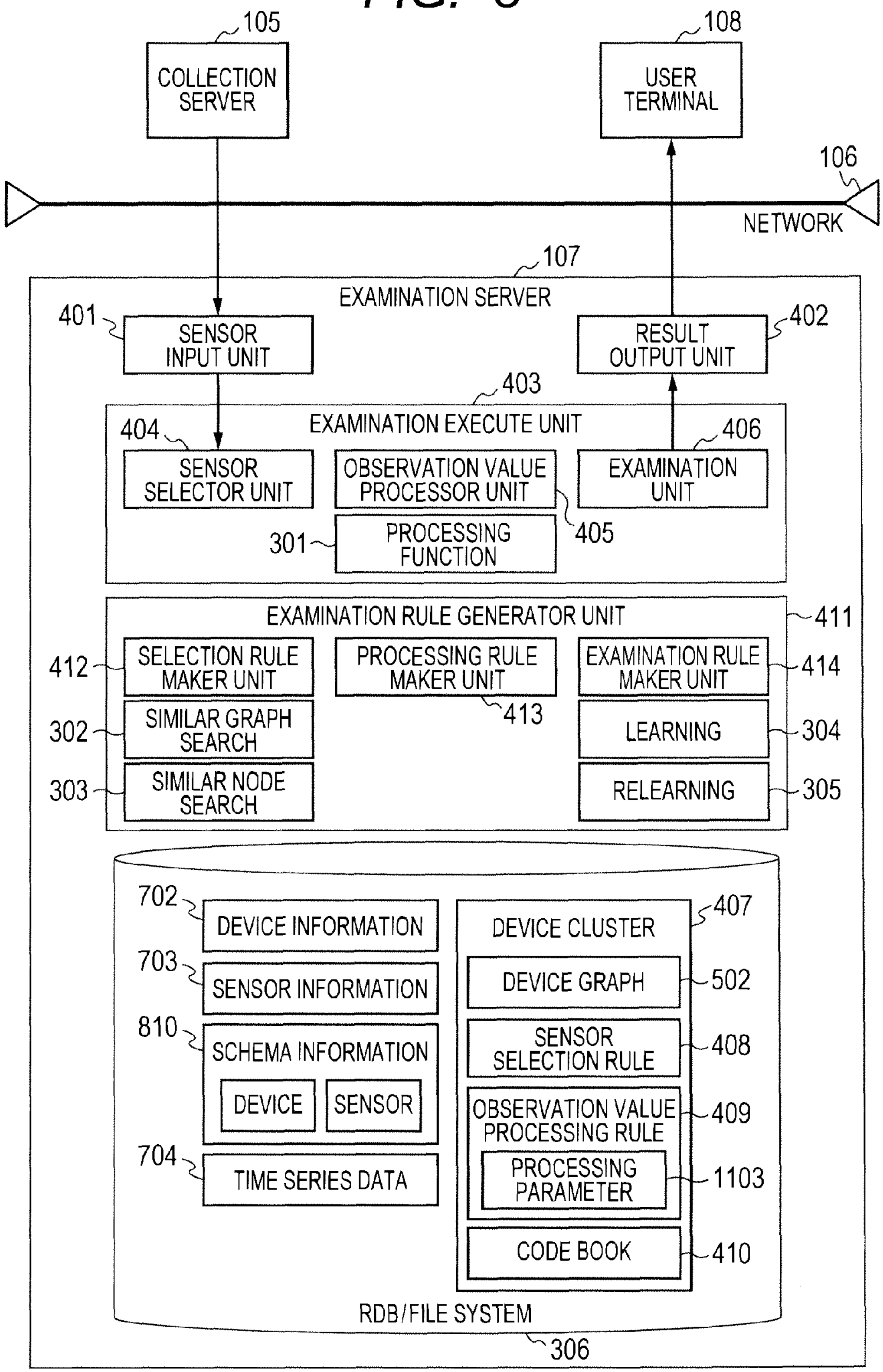

105
COLLECTION SERVER
108
USER TERMINAL
106
NETWORK
107
EXAMINATION SERVER
401
SENSOR INPUT UNIT
402
RESULT OUTPUT UNIT
403
EXAMINATION EXECUTE UNIT
404
SENSOR SELECTOR UNIT
OBSERVATION VALUE PROCESSOR UNIT
405
406
EXAMINATION UNIT
301
PROCESSING FUNCTION
EXAMINATION RULE GENERATOR UNIT
411
412
SELECTION RULE MAKER UNIT
PROCESSING RULE MAKER UNIT
413
EXAMINATION RULE MAKER UNIT
414
302
SIMILAR GRAPH SEARCH
LEARNING
304
303
SIMILAR NODE SEARCH
RELEARNING
305
702
DEVICE INFORMATION
703
SENSOR INFORMATION
810
SCHEMA INFORMATION
DEVICE
SENSOR
704
TIME SERIES DATA
DEVICE CLUSTER
407
DEVICE GRAPH
502
SENSOR SELECTION RULE
408
OBSERVATION VALUE PROCESSING RULE
409
PROCESSING PARAMETER
1103
CODE BOOK
410
RDB/FILE SYSTEM
306

FIG. 4

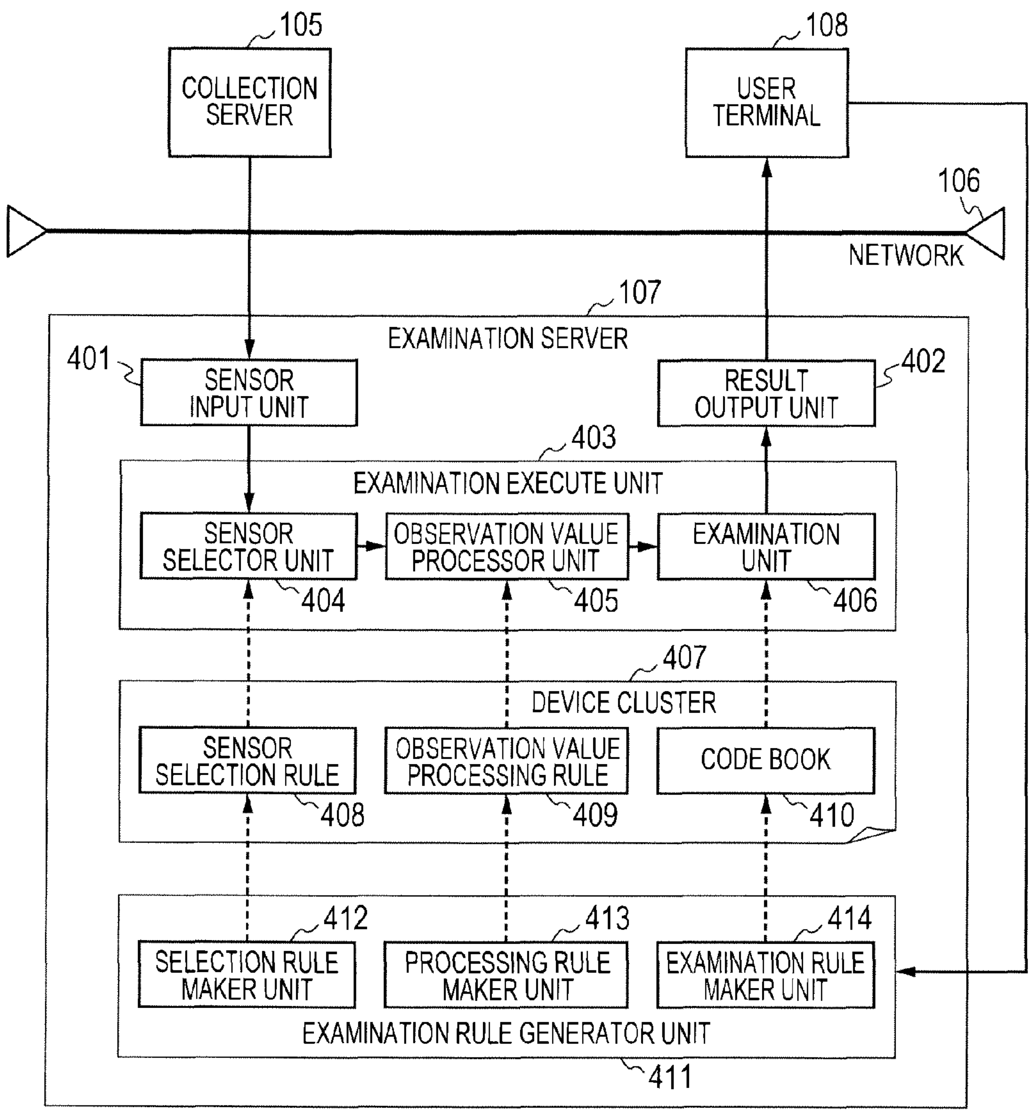

105
COLLECTION SERVER
108
USER TERMINAL
106
NETWORK
107
EXAMINATION SERVER
401
SENSOR INPUT UNIT
402
RESULT OUTPUT UNIT
403
EXAMINATION EXECUTE UNIT
SENSOR SELECTOR UNIT
404
OBSERVATION VALUE PROCESSOR UNIT
405
EXAMINATION UNIT
406
407
DEVICE CLUSTER
SENSOR SELECTION RULE
408
OBSERVATION VALUE PROCESSING RULE
409
CODE BOOK
410
412
SELECTION RULE MAKER UNIT
413
PROCESSING RULE MAKER UNIT
414
EXAMINATION RULE MAKER UNIT
EXAMINATION RULE GENERATOR UNIT
411

FIG. 5

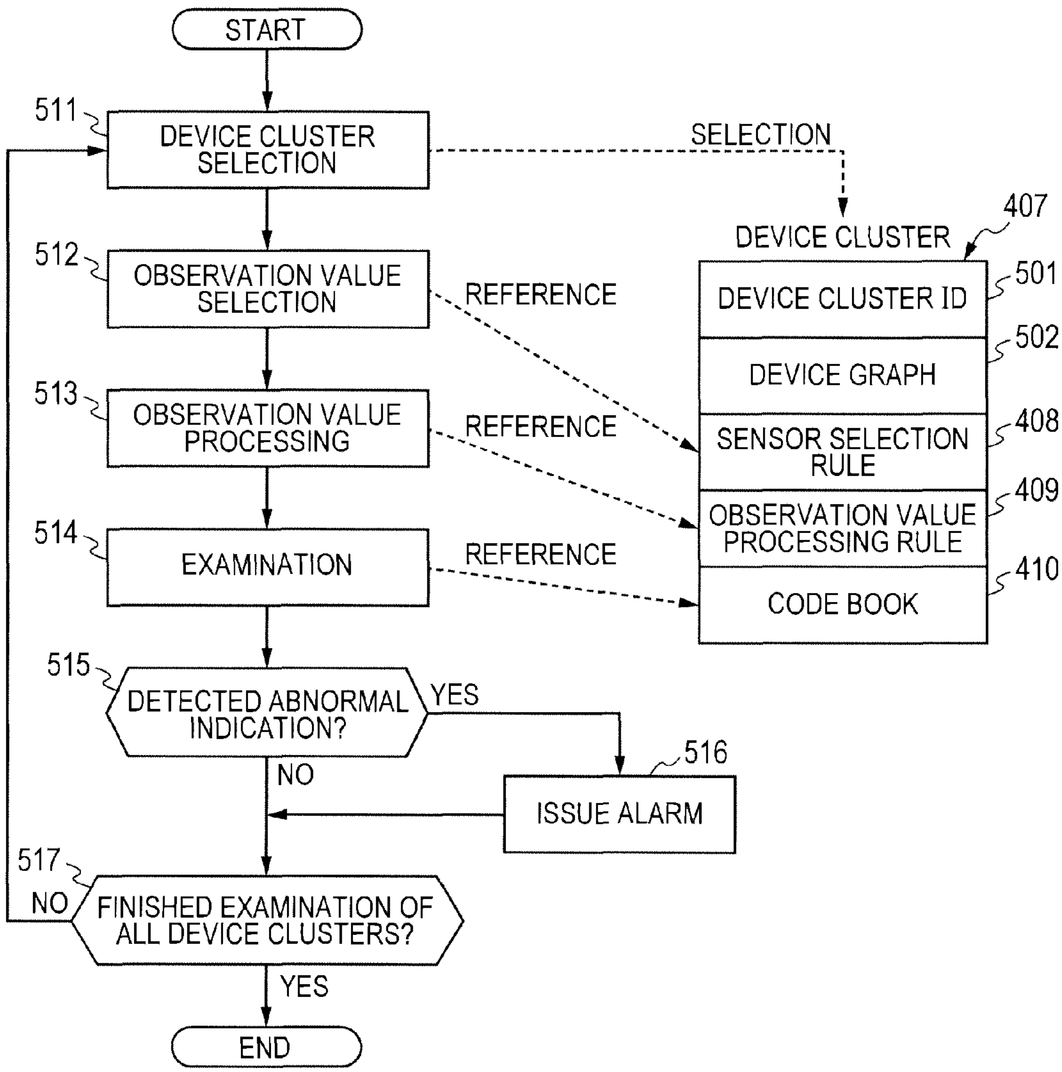

START
511
DEVICE CLUSTER SELECTION
SELECTION
407
DEVICE CLUSTER
512
OBSERVATION VALUE SELECTION
REFERENCE
DEVICE CLUSTER ID
501
DEVICE GRAPH
502
513
OBSERVATION VALUE PROCESSING
REFERENCE
SENSOR SELECTION RULE
408
OBSERVATION VALUE PROCESSING RULE
409
514
EXAMINATION
REFERENCE
CODE BOOK
410
515
DETECTED ABNORMAL INDICATION?
YES
NO
516
ISSUE ALARM
517
NO
FINISHED EXAMINATION OF ALL DEVICE CLUSTERS?
YES
END

FIG. 6

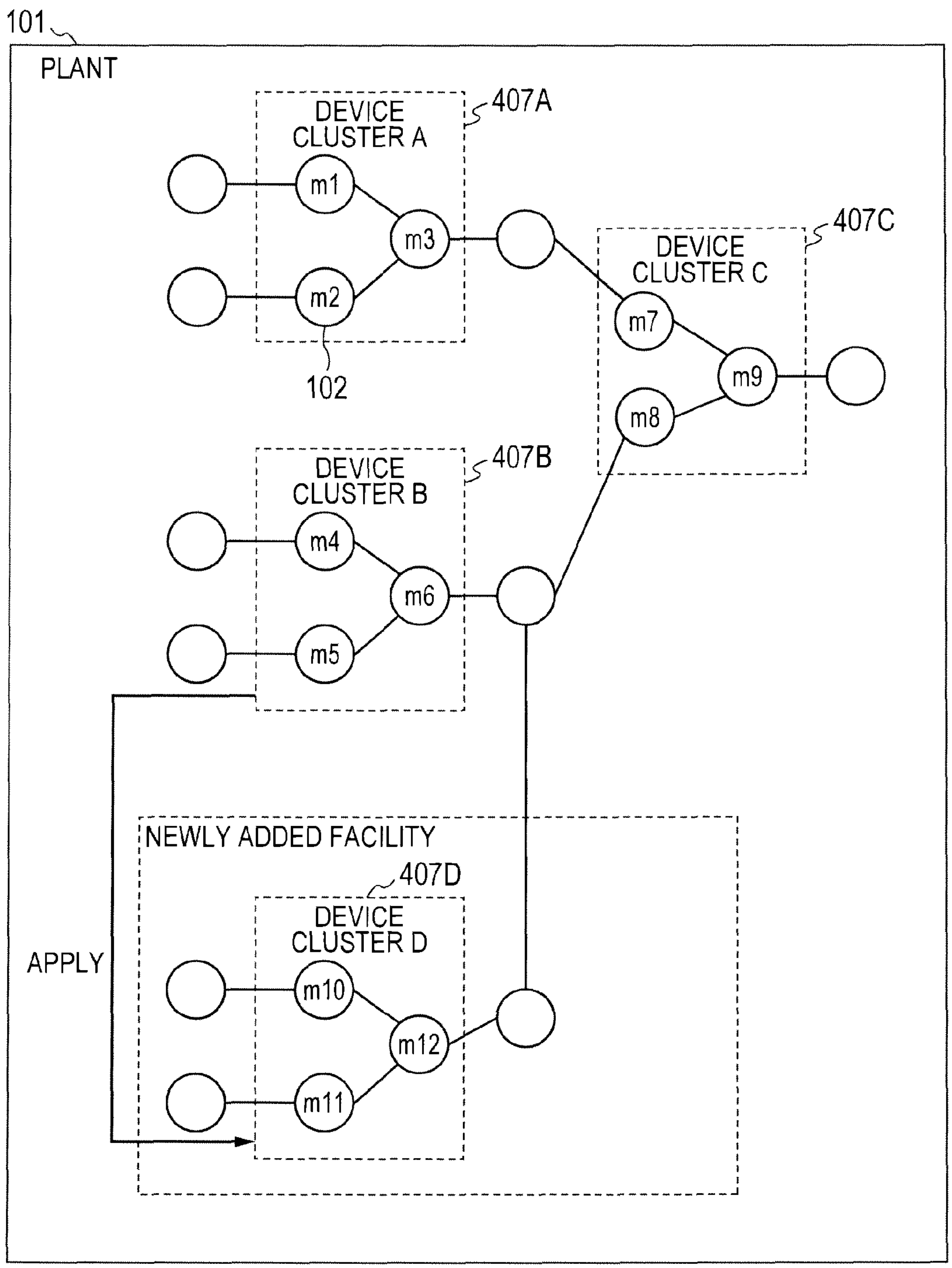

101
PLANT
DEVICE CLUSTER A
407A
m1
m2
m3
102
DEVICE CLUSTER C
407C
m7
m8
m9
DEVICE CLUSTER B
407B
m4
m5
m6
NEWLY ADDED FACILITY
407D
DEVICE CLUSTER D
APPLY
m10
m11
m12

FIG. 7

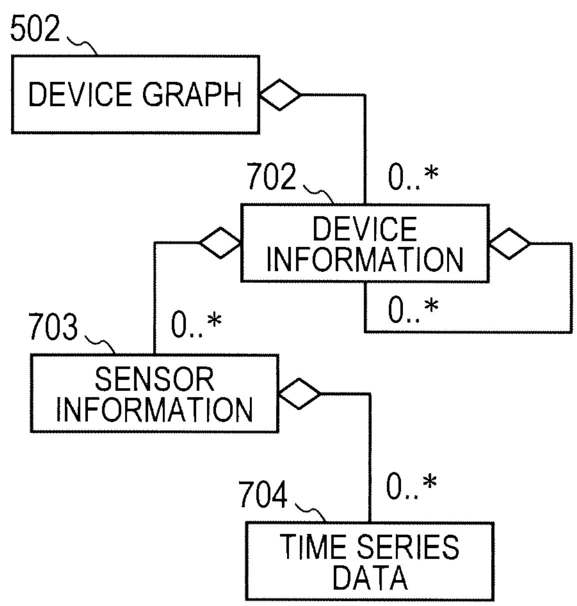

502
DEVICE GRAPH
702
0..*
DEVICE INFORMATION
0..*
703
0..*
SENSOR INFORMATION
704
0..*
TIME SERIES DATA

FIG. 8

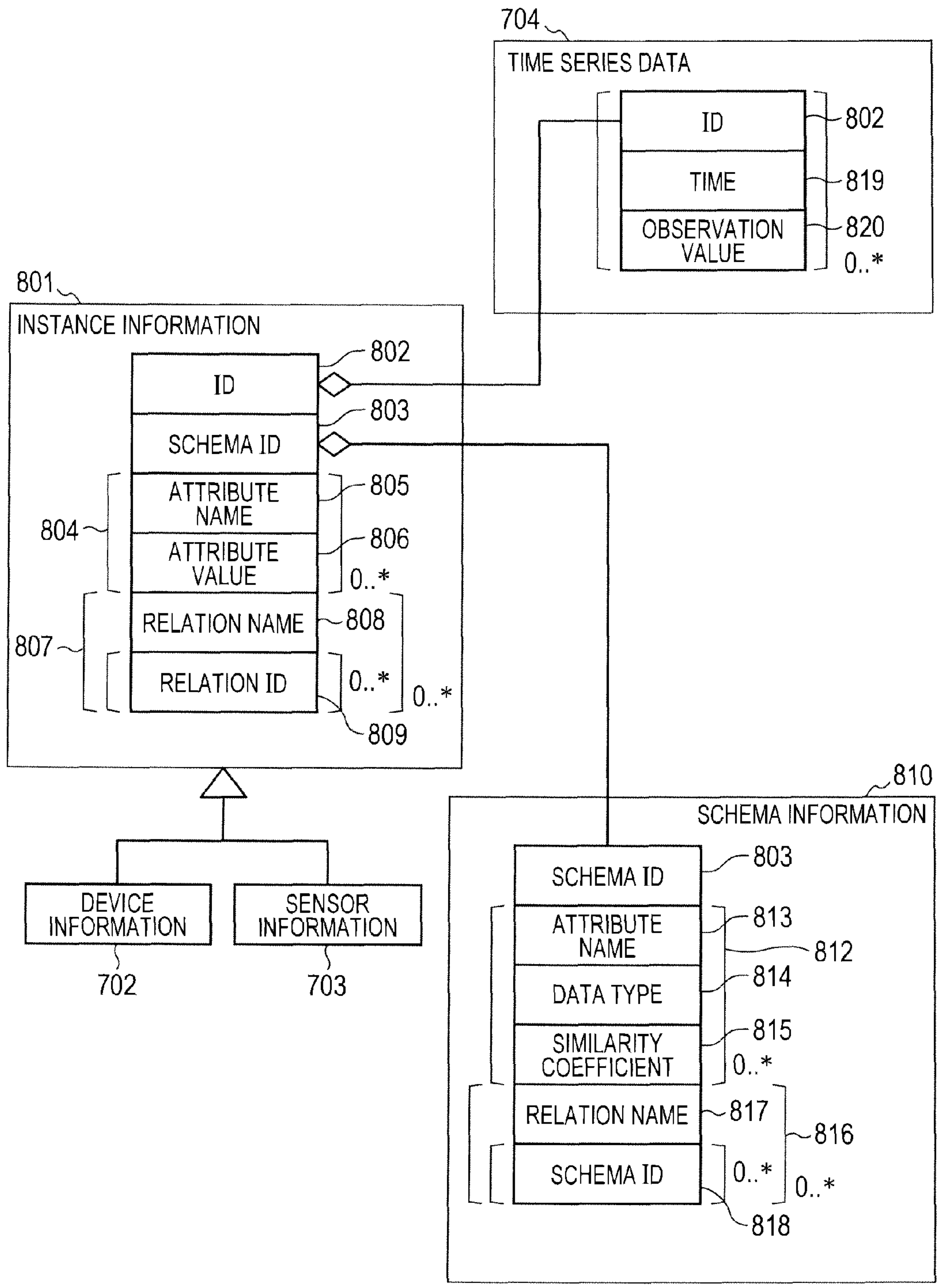
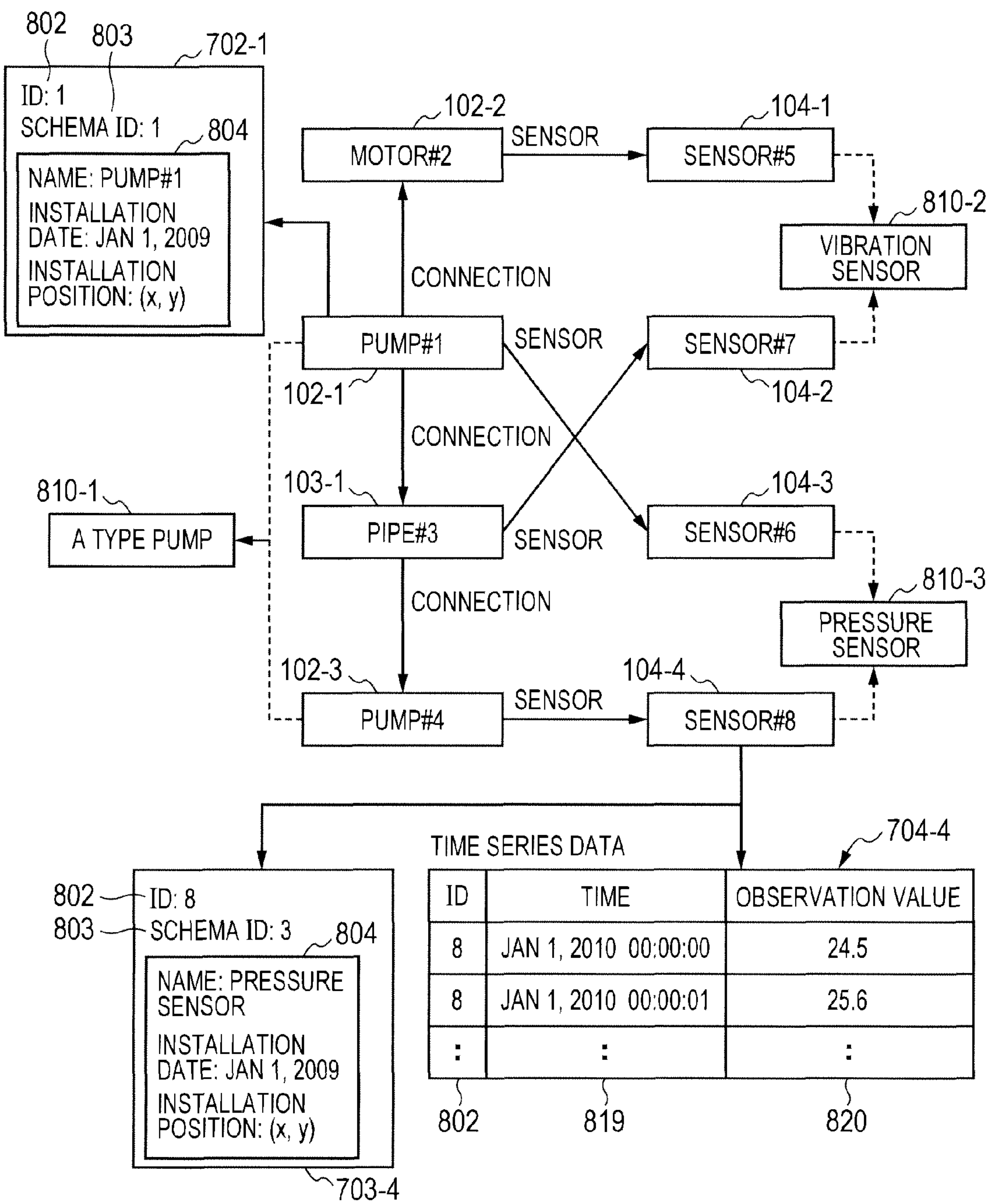

704
TIME SERIES DATA
ID
802
TIME
819
OBSERVATION VALUE
820
0..*
801
INSTANCE INFORMATION
ID
802
SCHEMA ID
803
ATTRIBUTE NAME
805
804
ATTRIBUTE VALUE
806
0..*
RELATION NAME
808
807
RELATION ID
0..*
0..*
809
DEVICE INFORMATION
702
SENSOR INFORMATION
703
810
SCHEMA INFORMATION
SCHEMA ID
803
ATTRIBUTE NAME
813
812
DATA TYPE
814
SIMILARITY COEFFICIENT
815
0..*
RELATION NAME
817
816
SCHEMA ID
0..*
0..*
818

FIG. 9



ID	TIME	OBSERVATION VALUE
8	JAN 1, 2010 00:00:00	24.5
8	JAN 1, 2010 00:00:01	25.6
:	:	:

FIG. 10

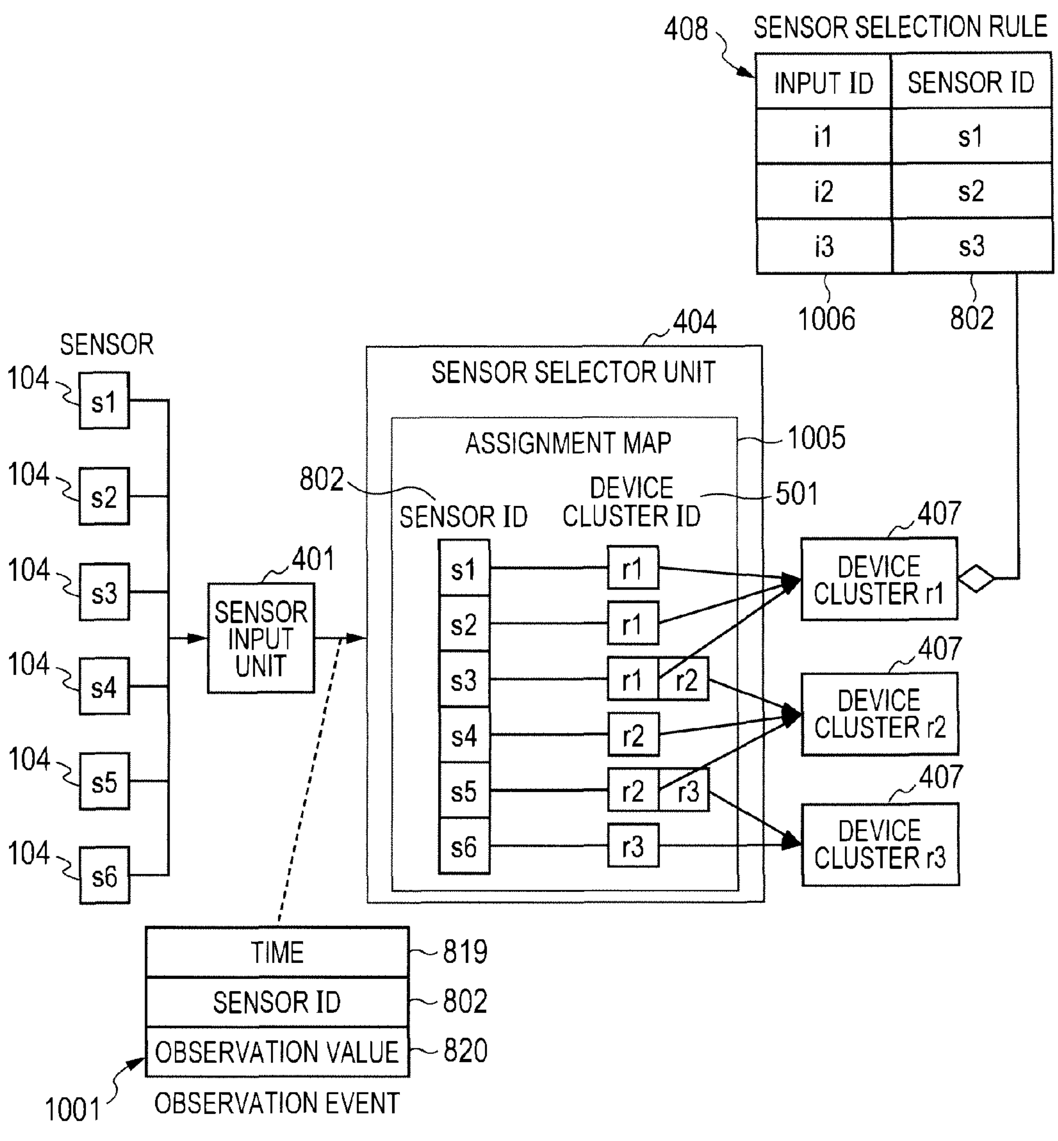

408
SENSOR SELECTION RULE
INPUT ID
SENSOR ID
i1
s1
i2
s2
i3
s3
1006
802
404
SENSOR SELECTOR UNIT
ASSIGNMENT MAP
1005
802
SENSOR ID
DEVICE CLUSTER ID
501
SENSOR
104
s1
s2
s3
s4
s5
s6
401
SENSOR INPUT UNIT
r1
r2
r3
407
DEVICE CLUSTER r1
DEVICE CLUSTER r2
DEVICE CLUSTER r3
TIME
819
SENSOR ID
802
OBSERVATION VALUE
820
1001
OBSERVATION EVENT

FIG. 11A

OBSERVATION VALUE PROCESSING RULE 409

ELEMENT ID	INPUT ID	PROCESSING FUNCTION	PROCESSING PARAMETER
v1	i1	NONE	NONE
v2	i2	MOVEMENT AVERAGE	5 SECONDS
v3	i3, i4	AVERAGE	NONE
v4	i5	FREQUENCY ANALYSIS	5 SECOND FFT, A POINT
v5	i5	FREQUENCY ANALYSIS	5 SECOND FFT, B POINT
v6	i5	FREQUENCY ANALYSIS	5 SECOND FFT, C POINT

1101 (rows) 1102 1006 301 1103

FIG. 11B

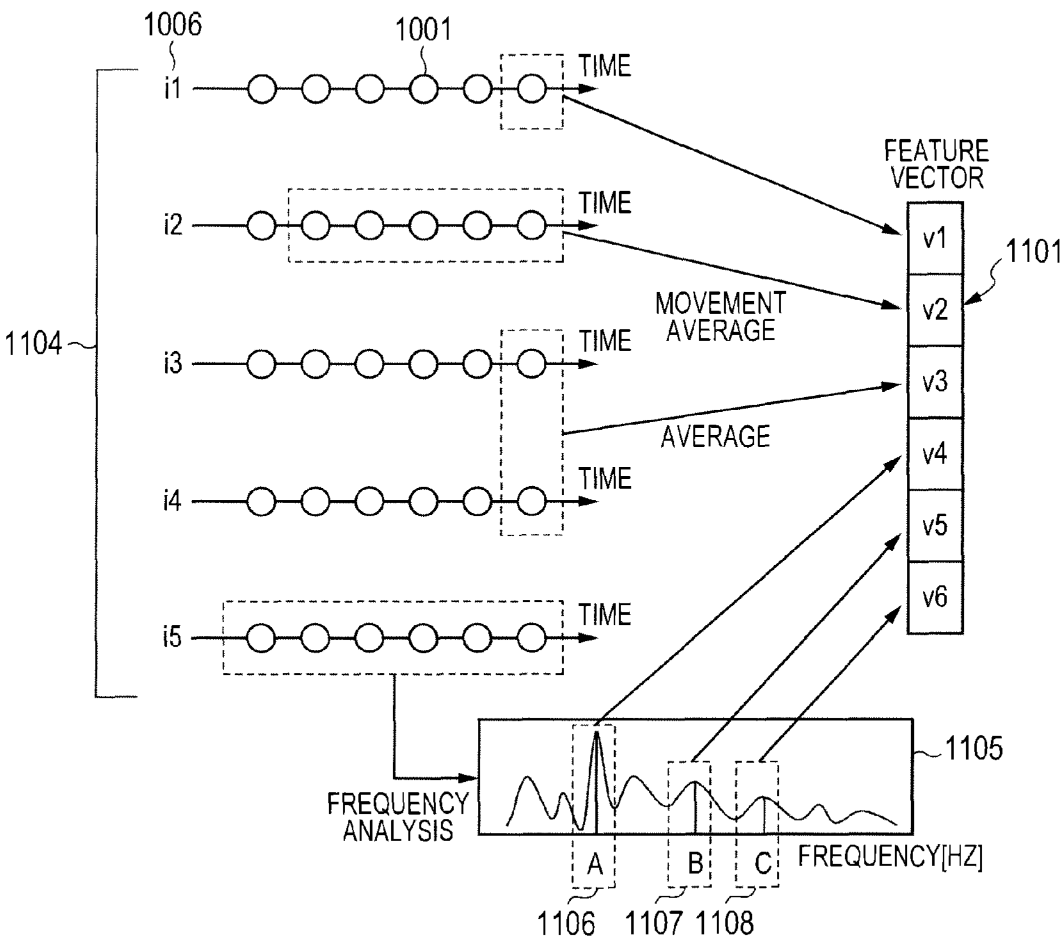


FIG. 12

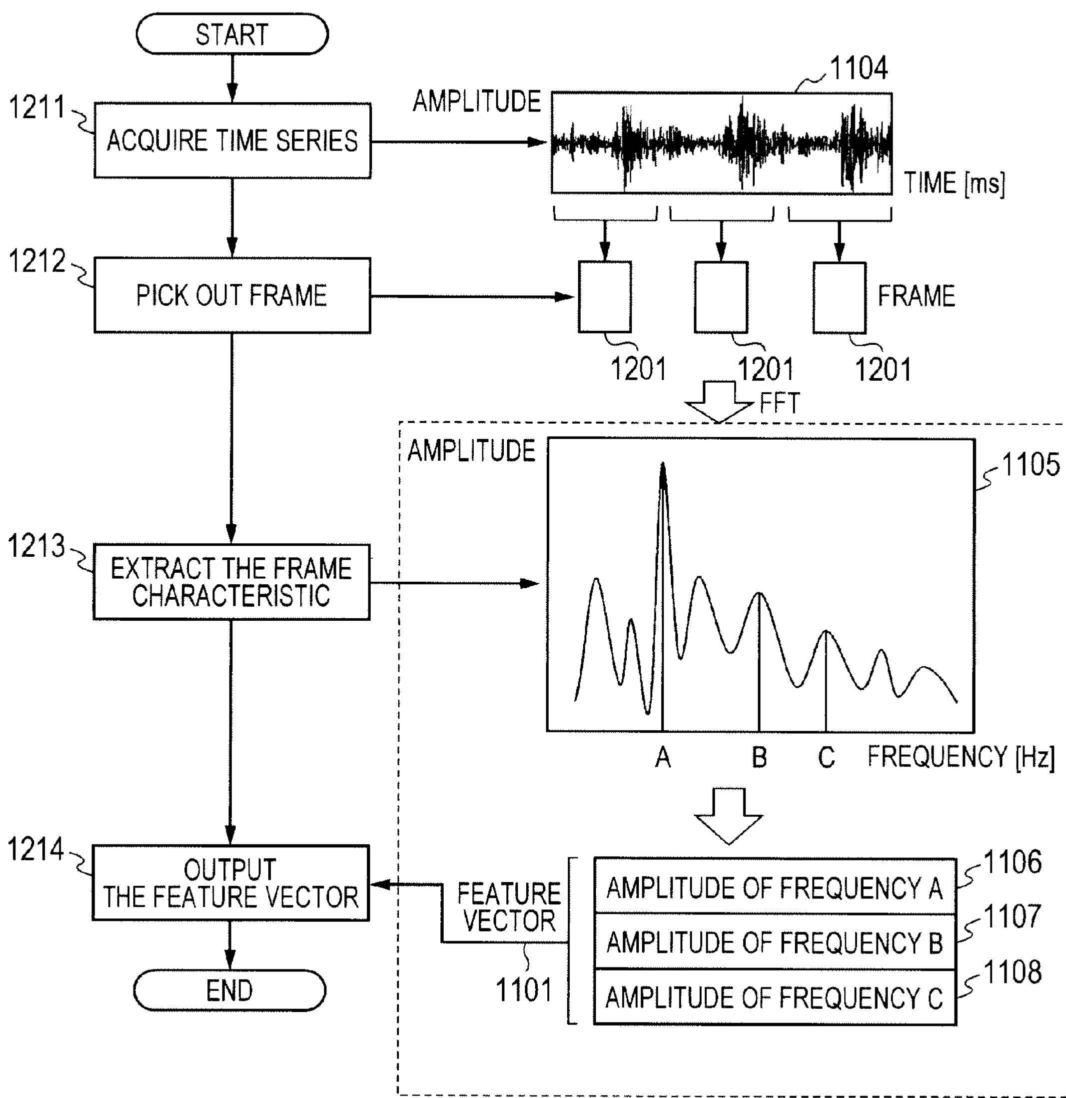

START
1211
ACQUIRE TIME SERIES
1212
PICK OUT FRAME
1213
EXTRACT THE FRAME CHARACTERISTIC
1214
OUTPUT THE FEATURE VECTOR
END
1104
AMPLITUDE
TIME [ms]
FRAME
1201
1201
1201
FFT
AMPLITUDE
1105
A
B
C
FREQUENCY [Hz]
FEATURE VECTOR
1101
AMPLITUDE OF FREQUENCY A
1106
AMPLITUDE OF FREQUENCY B
1107
AMPLITUDE OF FREQUENCY C
1108

FIG. 13A

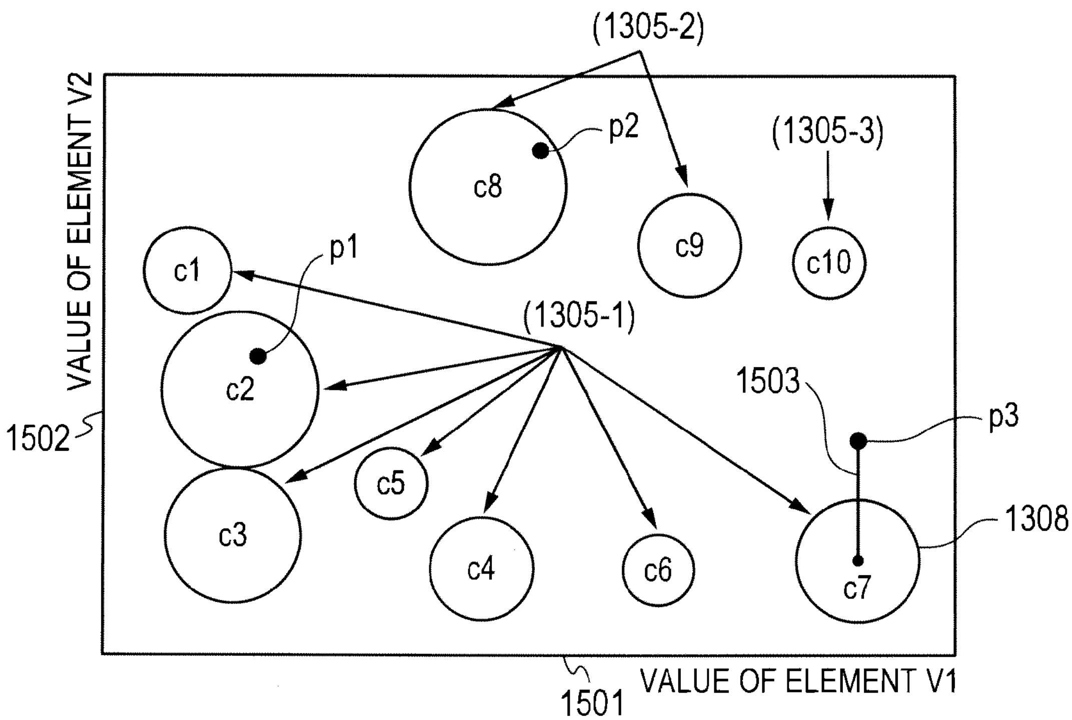


FIG. 13B

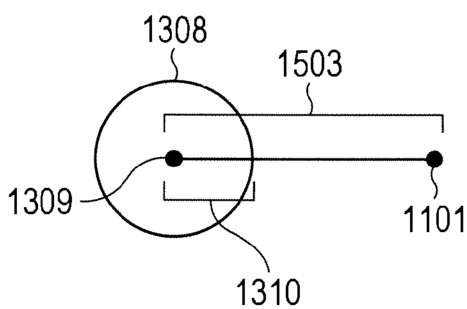


FIG. 13C

RELIABILITY 1302 = EVENT DISTANCE 1503 / EVENT CLUSTER RADIUS 1310

FIG. 14

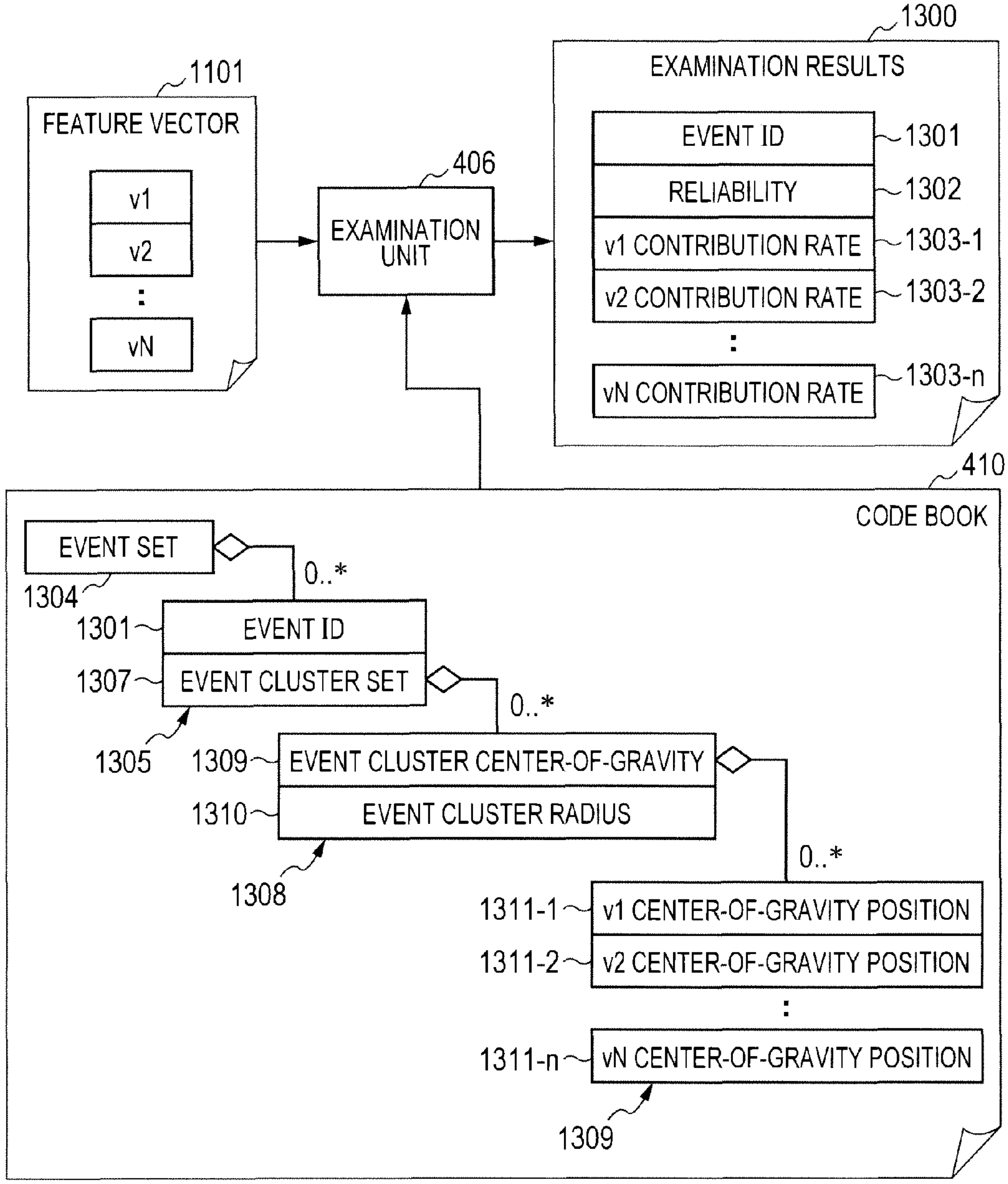

1101
FEATURE VECTOR
v1
v2
:
vN
406
EXAMINATION UNIT
1300
EXAMINATION RESULTS
EVENT ID
1301
RELIABILITY
1302
v1 CONTRIBUTION RATE
1303-1
v2 CONTRIBUTION RATE
1303-2
:
vN CONTRIBUTION RATE
1303-n
410
CODE BOOK
EVENT SET
1304
0..*
1301
EVENT ID
1307
EVENT CLUSTER SET
1305
0..*
1309
EVENT CLUSTER CENTER-OF-GRAVITY
1310
EVENT CLUSTER RADIUS
1308
0..*
1311-1
v1 CENTER-OF-GRAVITY POSITION
1311-2
v2 CENTER-OF-GRAVITY POSITION
:
1311-n
vN CENTER-OF-GRAVITY POSITION
1309

FIG. 15

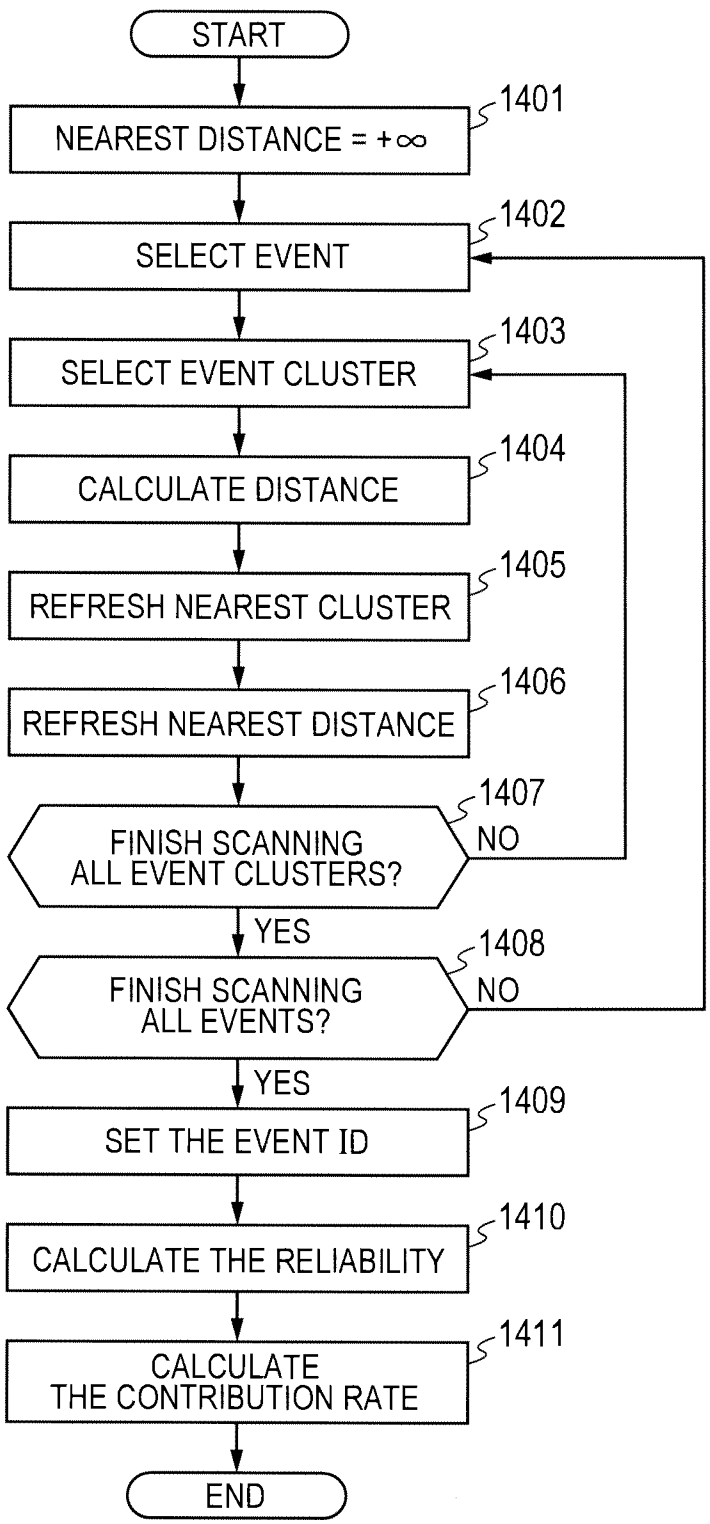

START
1401
NEAREST DISTANCE = +∞
1402
SELECT EVENT
1403
SELECT EVENT CLUSTER
1404
CALCULATE DISTANCE
1405
REFRESH NEAREST CLUSTER
1406
REFRESH NEAREST DISTANCE
1407
FINISH SCANNING ALL EVENT CLUSTERS?
NO
YES
1408
FINISH SCANNING ALL EVENTS?
NO
YES
1409
SET THE EVENT ID
1410
CALCULATE THE RELIABILITY
1411
CALCULATE THE CONTRIBUTION RATE
END

FIG. 16

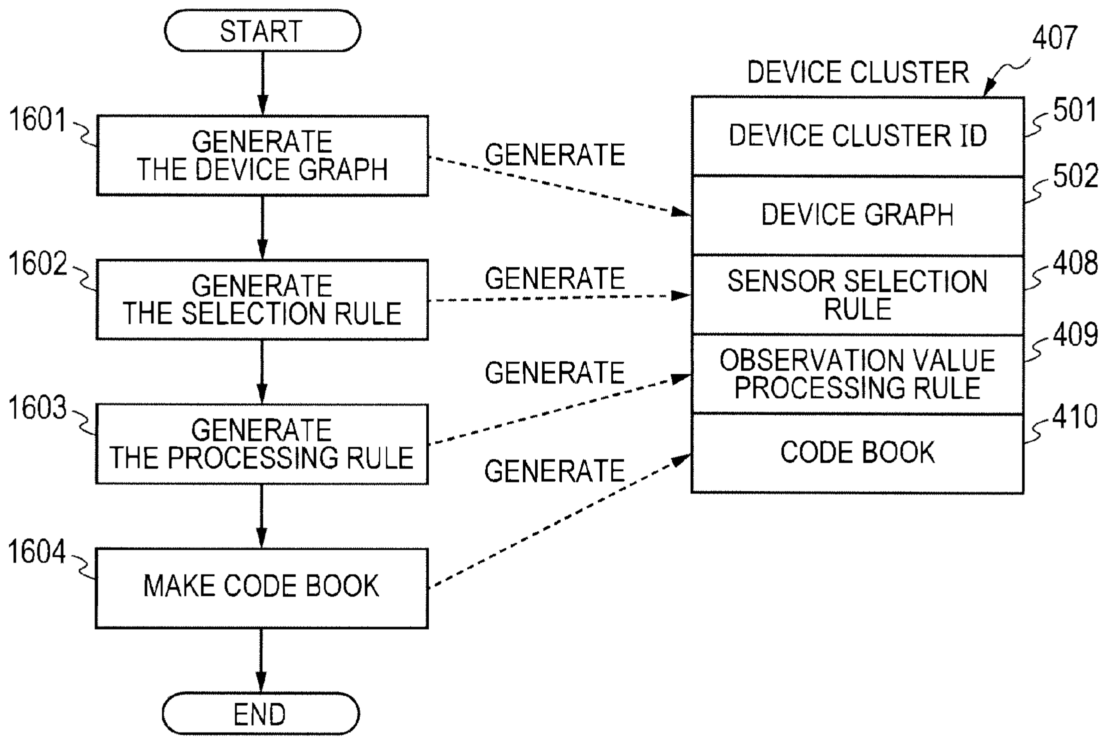

START
1601
GENERATE THE DEVICE GRAPH
1602
GENERATE THE SELECTION RULE
1603
GENERATE THE PROCESSING RULE
1604
MAKE CODE BOOK
END
GENERATE
GENERATE
GENERATE
GENERATE
407
DEVICE CLUSTER
DEVICE CLUSTER ID
501
DEVICE GRAPH
502
SENSOR SELECTION RULE
408
OBSERVATION VALUE PROCESSING RULE
409
CODE BOOK
410

FIG. 17

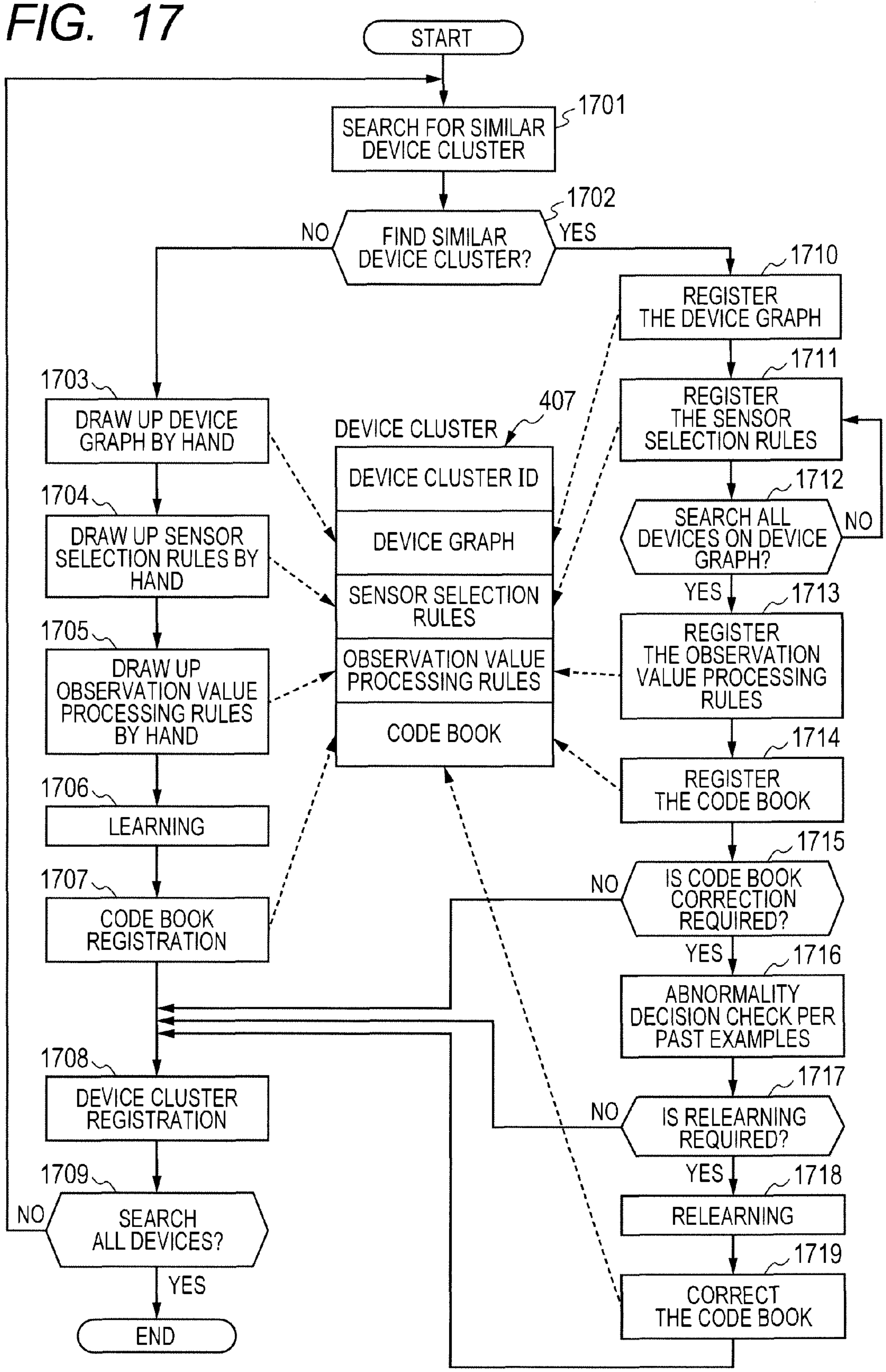

START
SEARCH FOR SIMILAR DEVICE CLUSTER
1701
FIND SIMILAR DEVICE CLUSTER?
1702
NO
YES
1703
DRAW UP DEVICE GRAPH BY HAND
1704
DRAW UP SENSOR SELECTION RULES BY HAND
1705
DRAW UP OBSERVATION VALUE PROCESSING RULES BY HAND
1706
LEARNING
1707
CODE BOOK REGISTRATION
1708
DEVICE CLUSTER REGISTRATION
1709
SEARCH ALL DEVICES?
NO
YES
END
DEVICE CLUSTER
407
DEVICE CLUSTER ID
DEVICE GRAPH
SENSOR SELECTION RULES
OBSERVATION VALUE PROCESSING RULES
CODE BOOK
1710
REGISTER THE DEVICE GRAPH
1711
REGISTER THE SENSOR SELECTION RULES
1712
SEARCH ALL DEVICES ON DEVICE GRAPH?
NO
YES
1713
REGISTER THE OBSERVATION VALUE PROCESSING RULES
1714
REGISTER THE CODE BOOK
1715
IS CODE BOOK CORRECTION REQUIRED?
NO
YES
1716
ABNORMALITY DECISION CHECK PER PAST EXAMPLES
1717
IS RELEARNING REQUIRED?
NO
YES
1718
RELEARNING
1719
CORRECT THE CODE BOOK

FIG. 18A

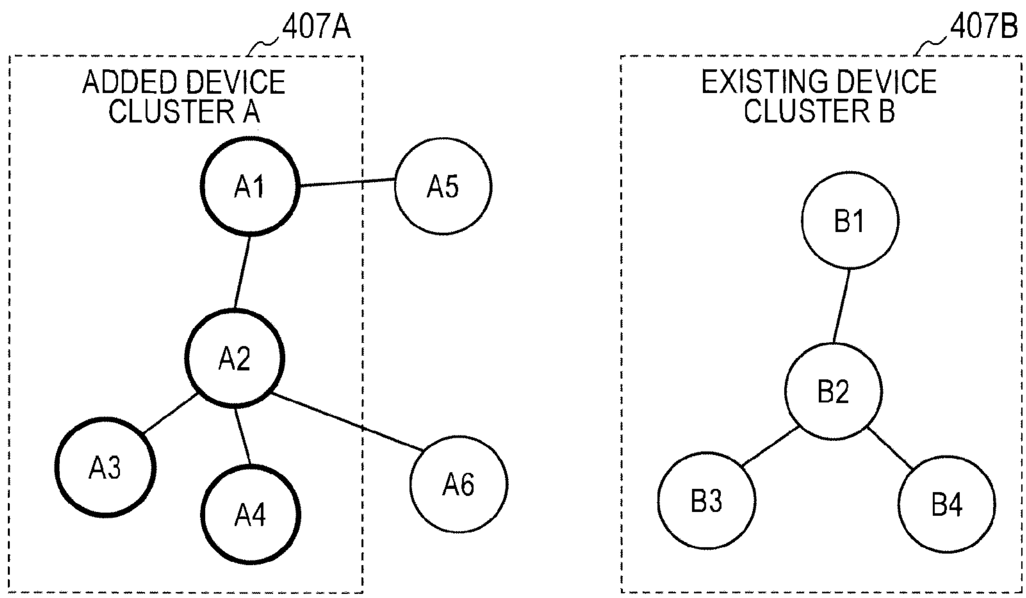


FIG. 18B

SENSOR SELECTION RULE FOR A

INPUT ID	SENSOR ID
i1	A1
i2	A2
i3	A3
i4	A4

408A

SENSOR MAP

SENSOR ID FOR A	SENSOR ID FOR B
B1	A1
B2	A2
B3	A3
B4	A4

2004

SENSOR SELECTION RULE FOR B

INPUT ID	SENSOR ID
i1	B1
i2	B2
i3	B3
i4	B4

408B

FIG. 19

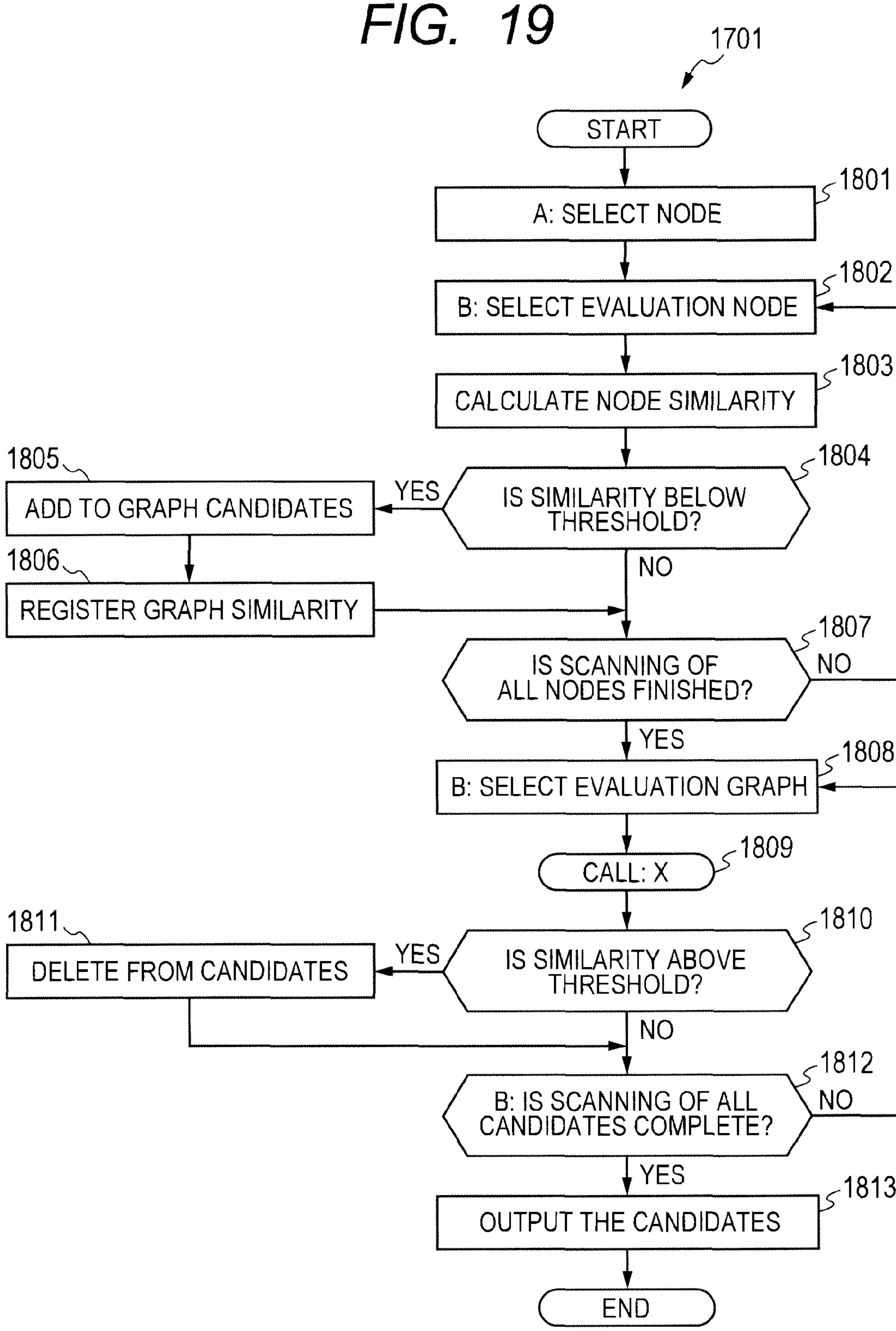

1701
START
A: SELECT NODE
1801
B: SELECT EVALUATION NODE
1802
CALCULATE NODE SIMILARITY
1803
IS SIMILARITY BELOW THRESHOLD?
1804
YES
NO
1805
ADD TO GRAPH CANDIDATES
1806
REGISTER GRAPH SIMILARITY
IS SCANNING OF ALL NODES FINISHED?
1807
NO
YES
B: SELECT EVALUATION GRAPH
1808
CALL: X
1809
IS SIMILARITY ABOVE THRESHOLD?
1810
YES
NO
1811
DELETE FROM CANDIDATES
B: IS SCANNING OF ALL CANDIDATES COMPLETE?
1812
NO
YES
OUTPUT THE CANDIDATES
1813
END

FIG. 20

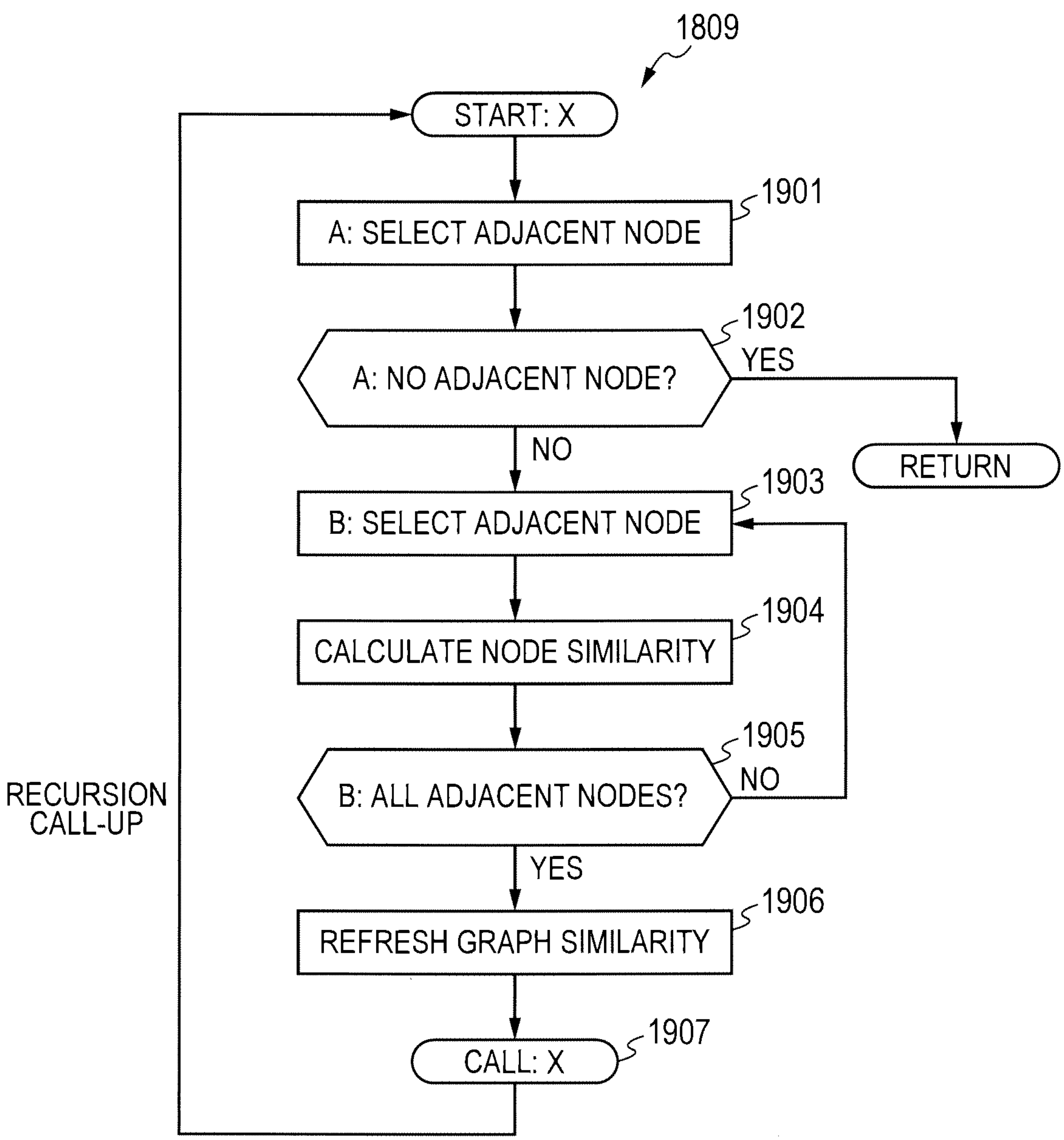

1809
START: X
A: SELECT ADJACENT NODE
1901
A: NO ADJACENT NODE?
1902
YES
NO
RETURN
B: SELECT ADJACENT NODE
1903
CALCULATE NODE SIMILARITY
1904
B: ALL ADJACENT NODES?
1905
NO
YES
REFRESH GRAPH SIMILARITY
1906
CALL: X
1907
RECURSION CALL-UP

FIG. 21

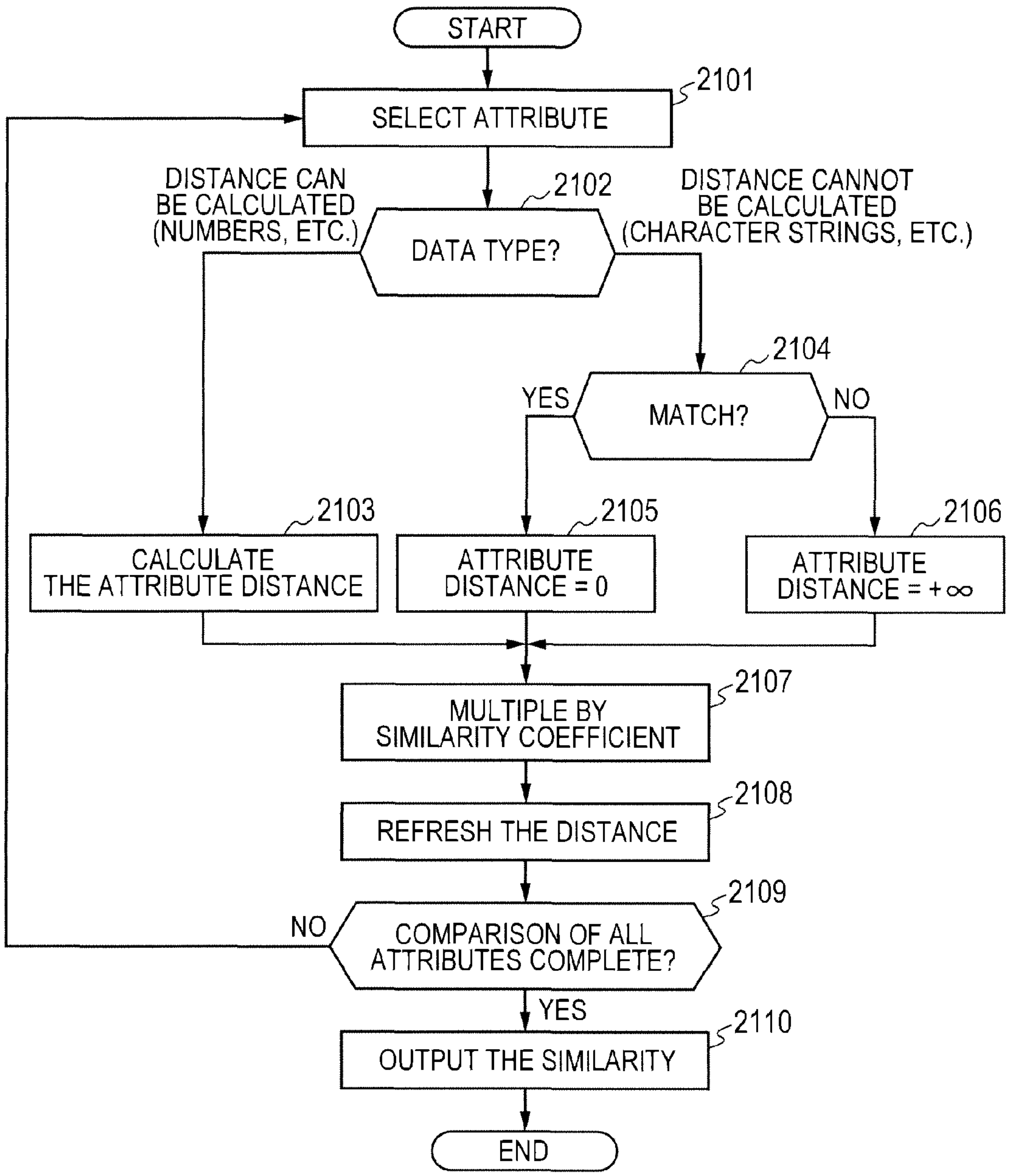

START
SELECT ATTRIBUTE
2101
DISTANCE CAN BE CALCULATED (NUMBERS, ETC.)
2102
DATA TYPE?
DISTANCE CANNOT BE CALCULATED (CHARACTER STRINGS, ETC.)
2104
MATCH?
YES
NO
2103
CALCULATE THE ATTRIBUTE DISTANCE
2105
ATTRIBUTE DISTANCE = 0
2106
ATTRIBUTE DISTANCE = +∞
2107
MULTIPLE BY SIMILARITY COEFFICIENT
2108
REFRESH THE DISTANCE
2109
NO
COMPARISON OF ALL ATTRIBUTES COMPLETE?
YES
2110
OUTPUT THE SIMILARITY
END

FIG. 22

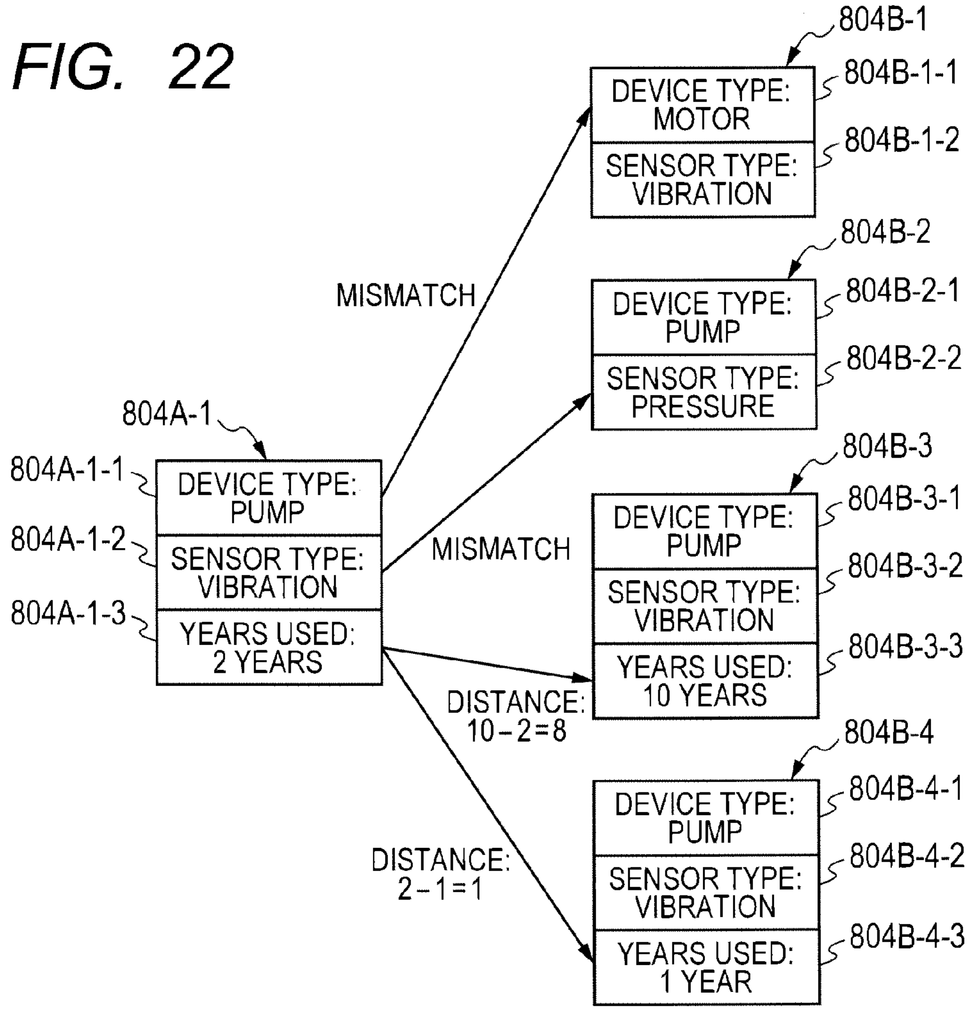

804B-1
DEVICE TYPE: MOTOR
804B-1-1
SENSOR TYPE: VIBRATION
804B-1-2
804B-2
DEVICE TYPE: PUMP
804B-2-1
SENSOR TYPE: PRESSURE
804B-2-2
MISMATCH
804A-1
804A-1-1
DEVICE TYPE: PUMP
804A-1-2
SENSOR TYPE: VIBRATION
804A-1-3
YEARS USED: 2 YEARS
MISMATCH
804B-3
DEVICE TYPE: PUMP
804B-3-1
SENSOR TYPE: VIBRATION
804B-3-2
YEARS USED: 10 YEARS
804B-3-3
DISTANCE: 10－2=8
804B-4
DEVICE TYPE: PUMP
804B-4-1
SENSOR TYPE: VIBRATION
804B-4-2
YEARS USED: 1 YEAR
804B-4-3
DISTANCE: 2－1=1

FIG. 23

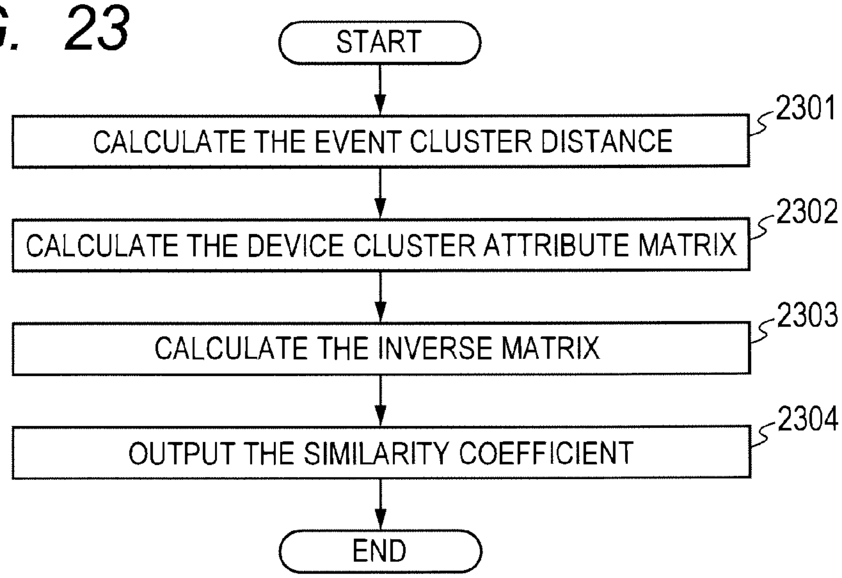

START
CALCULATE THE EVENT CLUSTER DISTANCE
2301
CALCULATE THE DEVICE CLUSTER ATTRIBUTE MATRIX
2302
CALCULATE THE INVERSE MATRIX
2303
OUTPUT THE SIMILARITY COEFFICIENT
2304
END

FIG. 24A

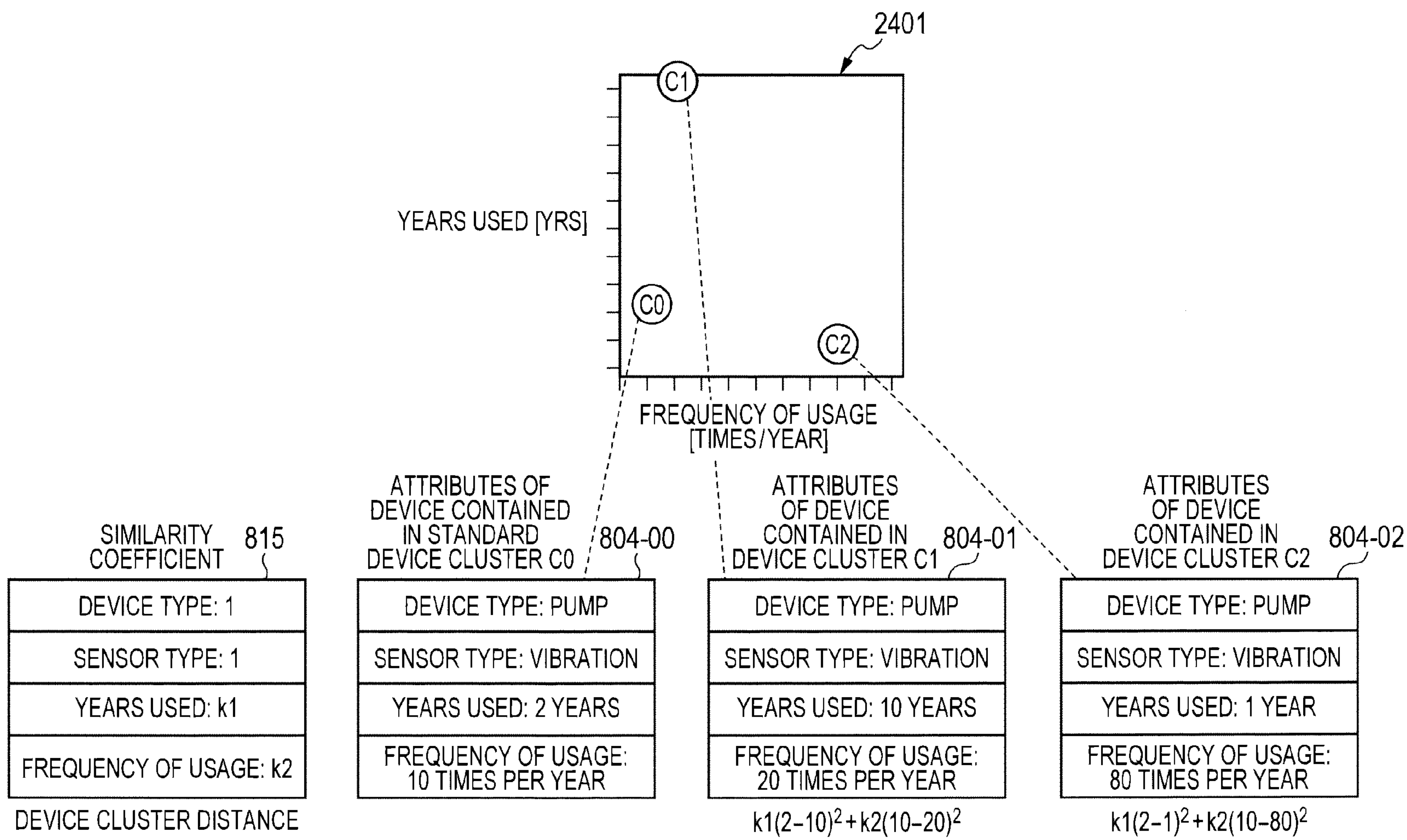

2401
C1
C0
C2
YEARS USED [YRS]
FREQUENCY OF USAGE [TIMES/YEAR]
SIMILARITY COEFFICIENT
815
DEVICE TYPE: 1
SENSOR TYPE: 1
YEARS USED: k1
FREQUENCY OF USAGE: k2
DEVICE CLUSTER DISTANCE
ATTRIBUTES OF DEVICE CONTAINED IN STANDARD DEVICE CLUSTER C0
804-00
DEVICE TYPE: PUMP
SENSOR TYPE: VIBRATION
YEARS USED: 2 YEARS
FREQUENCY OF USAGE: 10 TIMES PER YEAR
ATTRIBUTES OF DEVICE CONTAINED IN DEVICE CLUSTER C1
804-01
DEVICE TYPE: PUMP
SENSOR TYPE: VIBRATION
YEARS USED: 10 YEARS
FREQUENCY OF USAGE: 20 TIMES PER YEAR
k1(2−10)²+k2(10−20)²
ATTRIBUTES OF DEVICE CONTAINED IN DEVICE CLUSTER C2
804-02
DEVICE TYPE: PUMP
SENSOR TYPE: VIBRATION
YEARS USED: 1 YEAR
FREQUENCY OF USAGE: 80 TIMES PER YEAR
k1(2−1)²+k2(10−80)²

FIG. 24B

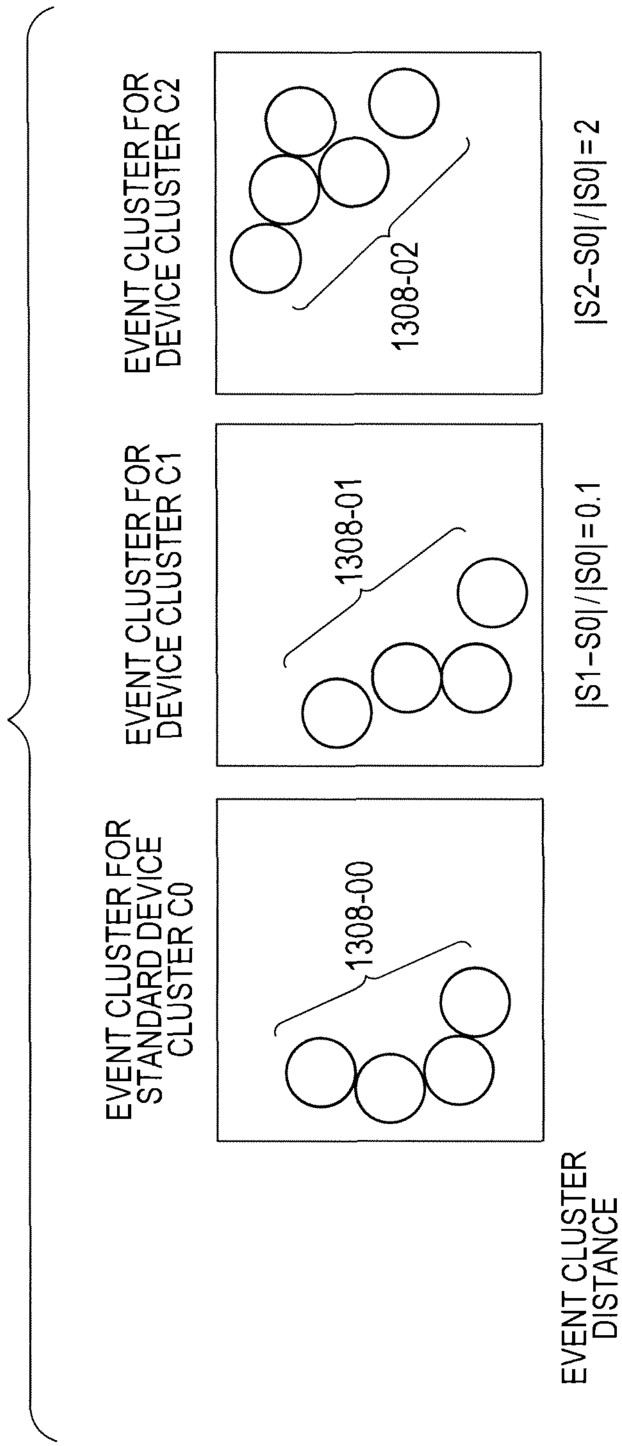
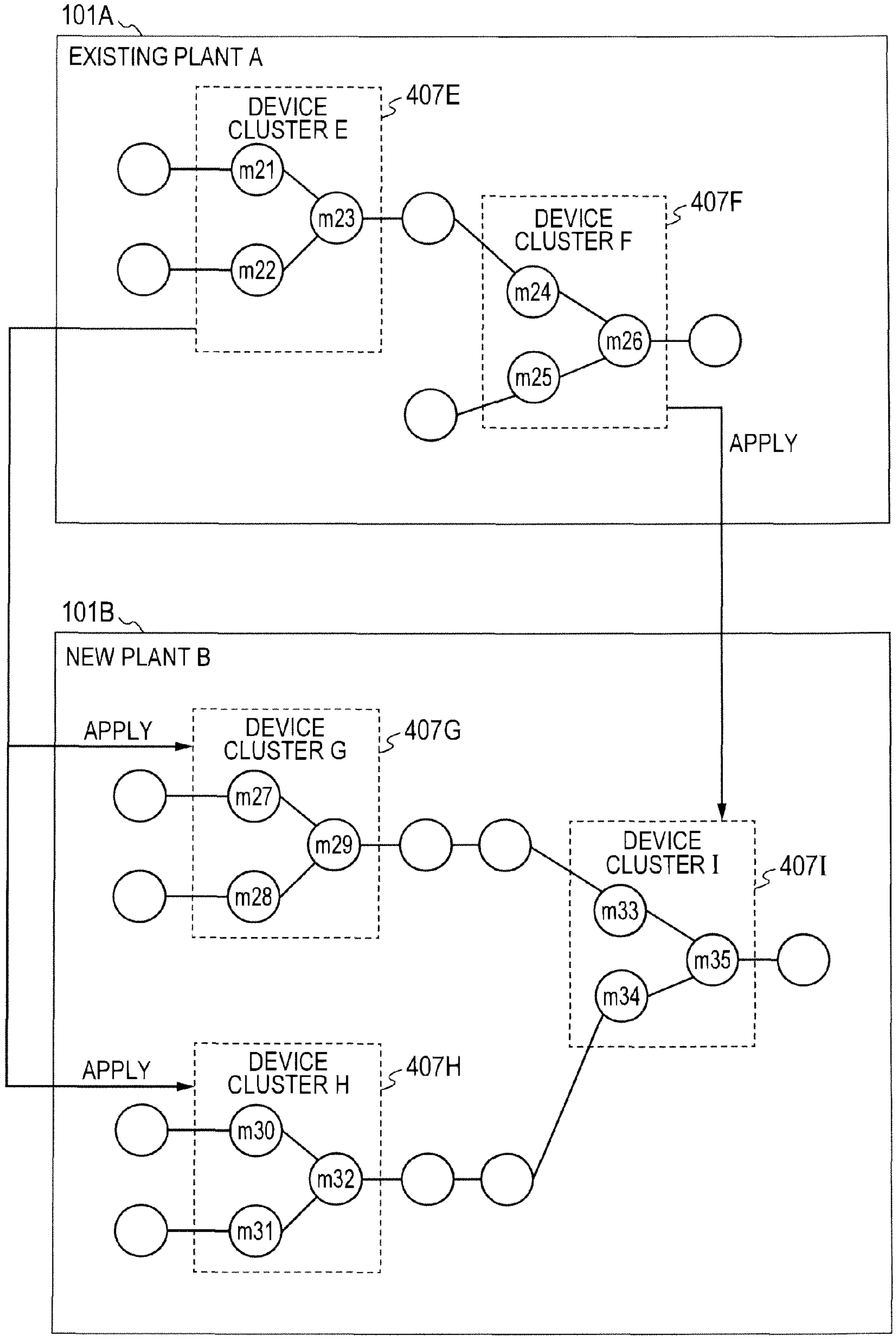

EVENT CLUSTER FOR STANDARD DEVICE CLUSTER C0
1308-00
EVENT CLUSTER FOR DEVICE CLUSTER C1
1308-01
EVENT CLUSTER FOR DEVICE CLUSTER C2
1308-02
EVENT CLUSTER DISTANCE
|S1−S0|/|S0|=0.1
|S2−S0|/|S0|=2

FIG. 25


101A
EXISTING PLANT A
DEVICE CLUSTER E
407E
m21
m22
m23
DEVICE CLUSTER F
407F
m24
m25
m26
APPLY
101B
NEW PLANT B
APPLY
DEVICE CLUSTER G
407G
m27
m28
m29
DEVICE CLUSTER I
407I
m33
m34
m35
APPLY
DEVICE CLUSTER H
407H
m30
m31
m32

COMPUTER SYSTEM AND RULE GENERATION METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims priority from Japanese patent application JP 2010-113175 filed on May 17, 2010, the content of which is hereby incorporated by reference into this application.

TECHNICAL FIELD

The present invention relates to a computer system, and relates in particular to a computer system for examining a physical amount measured in a device, etc.

BACKGROUND ART

Plants such as thermal power plants and nuclear power plants utilize systems for swiftly detecting device abnormalities and maintaining device to ensure the safe operation of device within the plant. In these types of systems, sensors are installed in each device in order to detect indications of abnormal device or indications that might lead to abnormal device, and the systems collect physical amounts (hereafter, "quantities") measured by the sensors and by diagnose these accumulated physical quantities to diagnose abnormalities in each piece of device.

These device abnormalities can be diagnosed by establishing rules in advance that show what calculation formula to utilize for the measured physical quantity. The rules established for this type of diagnosis are sometimes generated by applying calculation formulas utilized in similar device structures in similar systems.

Japanese Unexamined Patent Application Publication No. 2007-094538 discloses for instance, an airport light maintenance system that extracts failure histories containing similar peripheral information when a failure has for example been found in the lights within an airport facility; and estimates the cause of the failure by comparing past failure histories with peripheral information on the environment (temperature, rainfall amount) where the failure occurred, the number of replacements of failed lights, the number of sub-stations, power cable total extension lengths between main station and sub-stations, and identical airports and identical type circuits.

The International Patent Publication No. WO03/055145 pamphlet discloses technology for estimating the cause of failure when a failure has been found in a communication path where a plurality of relay devices are coupled in numerous stages, by searching the failure histories of communication paths having a connecting structure similar to that (problem) communication path.

SUMMARY OF INVENTION

Technical Problems

Abnormality indicator diagnostic services for diagnosing a device abnormality or an indication leading to a device abnormality require that new rules be written for diagnosing abnormalities when providing diagnostic services to new customers or when the customer's device has been modified or additions to the device have been made.

Abnormality indicator diagnosis of the related art utilizing vector quantize clustering is capable of making a diagnosis by using statistical techniques to analyze plural measured physi-

cal quantities, in other words, observation values, and so can diagnose an abnormality without analyzing the cause of the failure as performed in the previously described technology of the related art.

However, when making an abnormality indicator diagnosis using VQC to diagnose a large number of unrelated observation values, the problem of so-called, "curse of dimensionality" occurs and the abnormality detection accuracy worsens. In other words, increasing the observation values increases the number of quantitative parameters for indicating the abnormal phenomenon. Increasing the number of parameters serves to exponentially increase the number of abnormal phenomenon patterns so that pinpointing the abnormality becomes impossible.

Abnormality indicator diagnosis using VQC therefore required selecting the observation values needed in the diagnosis, but in the related art the administrator or person in charge selected these observation values through trial-and-error or through past experience. Selection of these observation values also requires many man-hours. Rules must be drawn up for example for 20,000 sensors at a thermal power plant and a large number of man-hours are required for setting which observation values to measure.

The VQC moreover requires learning data (codebook) for making the diagnosis. In the related art however, the codebook must be newly made for relearning when the device structure is different, causing the problem that utilization is impossible until all the abnormal phenomenon have been accumulated as information.

The present invention has the object of providing rules for making a diagnosis in the maintenance system by way of VQC.

Solution to Problem

A typical aspect of the present invention disclosed in the present application is given as follows. Namely, a computer system including a plurality of sensors installed in plural devices to measure specified physical quantities and a server to diagnose the physical quantities sent from the sensor; and in which, the plural devices are classified into a first device groups and a plurality of second device groups; and the plural second device groups contain a plurality of second examination rules showing diagnosis methods for the physical quantities; and the server calculates the similarity between the first device group and each of the second device groups; and extracts a first examination rule set in the first device group from the plural second examination rules set in the plural second device groups based on the calculated similarity.

Advantageous Effects of Invention

The typical embodiment of the present invention renders the effect of reducing the man-hours for setting the examination rules in a new device.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a block diagram showing the system of the first embodiment of the present invention;

FIG. **2** is a block diagram showing the hardware structure of the examination server of the first embodiment of the present invention;

FIG. **3** is a block diagram showing the examination server function in the first embodiment of the present invention;

FIG. **4** is a block diagram showing the processing by the examination server in the first embodiment of the present invention;

FIG. **5** is a flow chart showing the diagnostic processing by the examination executer unit of the first embodiment of the present invention;

FIG. **6** is a descriptive drawing showing an example applying a device cluster to new devices in the first embodiment of the present invention;

FIG. **7** is a descriptive drawing showing the structure of the device graph in the first embodiment of the present invention;

FIG. **8** is a descriptive drawing showing the data structure of device information and sensor information in the first embodiment of the present invention;

FIG. **9** is a descriptive drawing showing a specific example of the device information and sensor information of the first embodiment of the present invention;

FIG. **10** is a descriptive drawing showing the structure of the sensor selector unit and sensor selection rule in the first embodiment of the present invention;

FIG. **11**A is a descriptive drawing showing an observation value processing rule of the first embodiment of the present invention;

FIG. **11**B is a descriptive drawing showing an example of processing by the observation value processor unit in the first embodiment of the present invention;

FIG. **12** is a flow chart showing frequency analysis by the observation value processor unit in the first embodiment of the present invention;

FIG. **13**A is a descriptive drawing showing an example of the event distribution in the first embodiment of the present invention;

FIG. **13**B is a descriptive drawing showing the relation between the event cluster and the feature vector in the first embodiment of the present invention;

FIG. **13**C is a descriptive drawing showing the (math) function for calculating the reliability in the first embodiment of the present invention;

FIG. **14** is descriptive drawing showing the input/output data for VQC by the examination unit of the first embodiment of the present invention;

FIG. **15** is a flowchart showing the VQC by the examination unit of the first embodiment of the present invention;

FIG. **16** is a flow chart showing an overview of the processing for generating a device cluster in the first embodiment of the present invention;

FIG. **17** is a flow chart showing in detail the processing for generating a device cluster in the first embodiment of the present invention;

FIG. **18**A is a descriptive drawing showing a specific example for acquiring similar device graphs in the first embodiment of the present invention;

FIG. **18**B is a descriptive drawing showing the generation of a sensor selection rule in the first embodiment of the present invention;

FIG. **19** is a flow chart showing the procedure for acquiring similar device graphs in the first embodiment of the present invention;

FIG. **20** is a flow chart showing the method for calculating the similarity of the device graphs in the first embodiment of the present invention;

FIG. **21** is a flow chart showing the procedure for calculating the similarity of the nodes in the first embodiment of the present invention;

FIG. **22** is a descriptive drawing showing a specific example of calculating the attribute distance in the first embodiment of the present invention;

FIG. **23** is a flow chart showing the procedure for calculating the similarity coefficient in the first embodiment of the present invention;

FIG. **24**A is a descriptive drawing showing an example of the device cluster distance in the first embodiment of the present invention;

FIG. **24**B is a descriptive drawing showing an example of the event cluster distance in the first embodiment of the present invention;

FIG. **25** is a descriptive drawing showing an example of applying a device cluster to a new plant in the second embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

First Embodiment

FIG. **1** is a block diagram showing the system of the first embodiment of the present invention.

The system of the embodiment of the present invention includes the sensors **104**, a collection server **105**, a network **106**, and an examination server **107**.

The sensors **104** are respectively mounted in the devices **102** and pipes **103** installed within the plant **101** and measure the observation values such as vibration, heat, or rotation speed generated in the devices **102** and pipes **103**. A plant **101** is an electrical generating plant or factory, etc. The plant **101** contains the devices **102** and the pipes **103**. The devices **102** are a motor or a pump, etc., and the pipes **103** are pipes or cables that connect the devices **102** to each other. The collection server **105** collects observation values measured by the sensors. The collection server **105** sends the measured observation values to the examination server **107** byway of the network **106**.

In the present embodiment the plant **101** is an electrical power plant and so on but if a system for measuring the observation values by way of the sensor **104**, and collecting measured observation values, then the system can apply to any plant.

The network **106** is a LAN (Local Area Network), WAN (Wide Area Network) or may be any network of the Internet. The examination server **107** analyzes the observation values sent from the collection server **105** and judges whether or not a phenomenon indicating an abnormality has occurred. The examination server **107** sends the examination results to the user terminal **108** by way of the network **106**. The user terminal **108** displays the examination results so that the user can view the examination results.

FIG. **2** is a block diagram showing the hardware structure of the examination server **107** of the first embodiment of the present invention.

The examination server **107** includes an auxiliary storage device **202**, a CPU**203**, a network adapter **204**, an AC adapter **205**, a display **206**, and a keyboard **207**. When executing the program, the CPU**203** runs the program in a memory **201**, and utilizes the memory **201** as a temporary storage (buffer) area. The auxiliary storage device **202** is a non-volatile storage device (for example a magnetic disk drive) where a program executed by the CPU**203** and data, etc. are stored. The CPU**203** executes the program in order to analyze the observation values measured by the sensors **104** and judges whether or not a phenomenon indicating an abnormality has occurred.

The network adapter **204** receives the observation value sent from the collection server **105** byway of the network **106**, and is also a network interface for sending results diagnosed in the CPU**203** to the user terminal **108** by way of the network

106. The AC adapter **205** is a power supply device for supplying electrical power to the examination server **107**.

The display **206** is an output device for displaying the examination results from the examination server **107** to allow viewing by the administrator. The keyboard **207** is an input device for allowing the administrator to input parameters for making a diagnosis.

FIG. **3** is a block diagram showing the function of the examination server **107** in the first embodiment of the present invention.

The examination server **107** includes a sensor input unit **401**, a result output unit **402**, an examination rule generator unit **411**, and an RDB**306**.

The sensor input unit **401** receives the observation values sent from the collection server **105**, and send the received observation values to the examination executer unit **403**. The result output unit **402** sends the results diagnosed (examined) by the examination executer unit **403** to the user terminal **108**.

The examination executer unit **403** includes a sensor selector unit **404**, an observation value processor unit **405**, an examination unit **406**, and a processor function **301**. The examination executer unit **403** judges whether or not a phenomenon indicating an abnormality has occurred based on the observation values that were sent.

The sensor selector unit **404** is a program for analyzing the observation values that were sent, and selecting which sensor observation values to utilize for the diagnosis. The observation value processor unit **405** is a program for processing the observation value utilized in functions such as Fourier transforms, and selecting which observation values among the processed observation values to utilize for the diagnosis. The examination unit **406** is a program for diagnosing the observation values by methods such as VQC described later on. The processor function **301** is a function utilized in the observation value processor unit **405**, and is a sub-routine of the observation value processor unit **405**.

The examination rule generator unit **411** includes a selection rule maker unit **412**, a processing rule maker unit **413**, an examination rule maker unit **414**, a similar graph search unit **302**, a similar node search unit **303**, a learning unit **304**, and a relearning unit **305**. Each program in the examination executer unit **403** diagnoses (or examines) the observation values by way of the rules made or rewritten by the examination rule generator unit **411**.

The selection rule maker unit **412** is a program for making selection rules utilized in the sensor selector unit **404**. The similar graph search unit **302** and the similar node search unit **303** are sub-routines of the selection rule maker unit **412**. The processing rule maker unit **413** is a program for making rules for processing observation values utilized in the observation value processor unit **405**. The examination rule maker unit **414** is a program for making examination rules utilized in the examination unit **406**. The learning unit **304** and the relearning unit **305** are sub-routines of the examination rule maker unit **414**.

The RDB**306** stores the device information **702**, the sensor information **703**, the schema information **810**, the time-series data **704**, and the device cluster **407**. The RDB**306** can be a file system or a relational DB (Database) mounted in the memory **201**.

The device information **704** is information showing what type of device **102** and pipe **103** are present within the system, and how the device **102** and pipe **103** are connected. The device information **702** is stored beforehand by the administrator and so on in the RDB**306**.

More specifically, the device information **702** contains an identifier showing the unique device **102** and pipe **103**, names of the device **102** or pipe **103** (e.g. pump), and the type of operation of the device **102** or pipe **103** (e.g. rotation), the installation date of the device **102** or pipe **103**, and an identifier showing the connected device **102** or pipe **103**, etc. The device information **702** is shown by numbers or character strings.

The sensor information **703** is information showing what the specifications are for each sensor inside the system. The administrator or other party stored the sensor information **703** beforehand in the RDB**306**.

More specifically, the sensor information **703** stores attribute information showing the identifiers or names of the connected device **102** or pipe **103**, the object for measurement (e.g. rotation speed, temperature, etc.) observation value units (e.g. rpm, ° C., and so on), and measurement period (e.g. minutes and so on). The sensor information **703** is shown by way of numbers or character strings.

The schema information **810** is information showing what type of information is stored in the device information **702** and the sensor information **703**. More specifically, the schema information **810** showing the device information **702**, includes an identifier showing the unique device **102** or pipe **103**, a name of the device **102** or pipe **103**, the type of operation of the device **102** or pipe **103**, the installation date of the device **102** or pipe **103**, and an identifier showing the connected device **102** or pipe **103**.

The schema information **810** showing the sensor information **703** further contains, identifiers showing the sensor information **703**, identifiers or names of the connected devices **102** or the pipes **103**, object for measurement (e.g. rotation speed, temperature, etc.), observation value units (e.g. rpm, ° C., and so on) and measurement period (e.g. 5 minutes and so on).

The time-series data **704** stores the observation values measured by the sensor **104** in their time-series order. More specifically, the measurement time, identifier showing the sensor **104** that made the measurement, and the observation value are stored in the time-series data **704**.

The device cluster **407** contains a device graph **502**, a sensor selection rule **408**, an observation value processing rule **409**, a processing parameter **1103**, and a code book **410**. Among the devices **102** and pipes **103**, the device cluster **407** is information on the device **102** and pipe **103** combinations that require diagnosis together. One device cluster may contain at least one device **102** or pipe **103**.

The device graph **502** contains identifiers showing each unique device **102** or pipe **103**, and information such as how the device **102** or pipe **103** is installed and at what distances. The device graph **502** for example contains information such as that a pump and pipe are connected, or information that a turbine and pipe are installed 30 centimeters apart.

Among the sensors **104** connected to the devices **102** or the pipe **103** shown in the device graph **502**; the sensor selection rule **408** contains information showing what observation values are utilized by which sensor **104**.

The observation value processing rule **409** contains information showing how to process observation values that were measured on the device **102** or the pipe **103** shown in the device graph **502**. The processing parameter **1103** is a parameter utilized in functions in cases where the observation value processing rule **409** is the function.

The codebook **410** stores parameters for making a diagnosis. Namely, the codebook **410** stores examination rules for diagnosing, what type of observation value shows what type of event at what numerical value.

FIG. **4** is a block diagram showing the processing by the examination server **107** in the first embodiment of the present invention.

The sensor selector unit **404** selects which sensor observation value to utilize for the diagnosis when an observation value is received from the collection server **105** by way of the sensor input unit **401**. Moreover in order to select the sensor, the sensor selector unit **404** refers to the sensor selection rule **408** made by the selection rule maker unit **412**.

When an observation value for a sensor selected by the sensor selector unit **404** is received, the observation value processor unit **405** processes the observation value that was received, and selects which observation value to utilize for the diagnosis from among the processed observation values. In order to process the observation value, the observation value processor unit **405** also refers to the observation value processing rule **409** made by the processing rule maker unit **413**.

When an observation value processed by the observation value processor unit **405** is received, the examination unit **406** proceeds to diagnose that received observation value. Moreover, in order to diagnose the observation value, the examination unit **406** searches the code book **410** made by the examination rule maker unit **414**.

FIG. **5** is a flow chart showing the diagnostic processing by the examination executer unit **403** of the first embodiment of the present invention.

The device cluster **407** shown in FIG. **5** includes a device cluster ID**501**, a device graph **502**, a sensor selection rule **408**, an observation value processing rule **409**, and a code book **410**. The device cluster ID**501** is an identifier showing a unique device cluster **407**.

The examination executer unit **403** implements the flow chart (processing) shown in FIG. **5** when the observation value sent from the collection server **105** is a fixed cumulative quantity for each device cluster **407**. In other words, when the observation value sent from the collection server **105** is a fixed cumulative quantity for each device cluster **407**, the examination executer unit **403** selects the device cluster **407** where the observation value has been accumulated (Step **511**). The examination executer unit **403** then sends the selected observation value for the device cluster **407** to the sensor selector unit **404**.

The sensor selector unit **404** selects which sensor observation value to utilize by searching the sensor selection rule **408** contained in the device cluster **407** selected in step **511** (step **512**). The sensor selector unit **404** then sends the selected sensor observation value to the observation value processor unit **405**.

The observation value processor unit **405** processes (step **513**) the observation value selected in step **512** by searching the observation value processing rule **409** contained in the device cluster **407** selected in step **511** (step **513**). The observation value processor unit **405** then sends the processed observation value to the examination unit **406**.

The examination unit **406** diagnoses the observation values processed in step **513** by searching the code book **410** contained in the device cluster **407** selected in step **511** (step **514**). There are plural observation values processed by the observation value processor unit **405** and each show a different phenomenon. These plural observation values are therefore shown by a feature vector. The examination unit **406** converts the observation values shown by the feature vector into scalar values in this step **514**.

The examination unit **406** compares the observation values converted into scalar values in step **514**, with pre-established threshold values (step **515**) and if those results are values showing the observation values are abnormal or namely if indications of an abnormality are detected, issues a warning (step **516**). The examination unit **406** may issue a warning by displaying a warning on a display **206** or may issue a warning by sending a message signifying a warning to the user terminal **108**. Information showing abnormality indications even other than a warning may be retained in the RDB**306**, etc.

In step **515**, when there is no observation value indicating an abnormality in step **515**, or after the warning was issued in step **516**, the examination executer unit **403** decides whether or not the diagnosis for all device clusters **407** has ended or not by judging whether the observation values sent from the collection server **105** have accumulated to a specified quantity or not (step **517**). If the diagnosis has not ended then the examination executer unit **403** returns to step **511**. If the diagnosis has ended then the examination executer unit **403** terminates the processing and waits for observation values to accumulate.

FIG. **6** is a descriptive drawing showing an example applying a device cluster **407** to a new device **102** in the first embodiment of the present invention.

FIG. **6** shows the connective relation of the device **102** or pipe **103** contained within the one plant **101**.

The device **102** and the pipe **103** are shown (m1 through m12) in FIG. **6**. Each of the devices **102** and pipes **103** are connected by way of a tree structure. The example shown in FIG. **6**, describes only the device **102** but the connectional relation may also include the pipe **103**. The connectional relation for the device **102** shown in FIG. **6** is a connectional relation for the device **102** contained the plant **101**, however a connectional relation within a specified department within the plant **101** is also allowed.

As already described, the connectional relation of the devices **102** requiring collective diagnosis of the observed observation values is shown by the device graph **502**, and the device clusters **407** are assigned to the device graph **502**. The device cluster **407** shown in FIG. **6** includes a device cluster **407**A assigned to the devices and pipes m1-m3, the device cluster **407**B assigned to the devices and pipes m4-m6, and the device cluster **407**C assigned to the devices and pipes m7-m9.

This drawing shows the case where a facility containing a new device **102** has been newly added to the plant **101**. Among the newly added plural devices **102**, the examination rule generator unit **411** of the present embodiment searches for device graphs **502** resembling the already existing device graph **502**, and generates a device cluster **407** for the newly added facility by applying a new device **102** to the device cluster **407** stored in the device graph **502** that was searched.

In the example shown in FIG. **6**, when the device graph **502** including the devices and pipes m4-m6, is similar to the device graph **502** including the devices and pipes m10-m12, the device cluster **407**D is generated for devices and pipes m10-m12 by applying the device cluster **407**B including the devices and pipes m4-m6 to the devices and pipes m10-m12.

FIG. **7** is a descriptive drawing showing the structure of the device graph **502** in the first embodiment of the present invention.

The device graph **502** includes 0 or one or more device information **702**, and these device information **702** are concentrated in the device graph **502**. In some cases the device information **702**, 0 or one or more device information **702** are contained in another device information **702**. If a pipe (pipe **103**) is for example connected to a pump (device **102**), then the device information **702** for the pipe is contained in the device information **702** for the pump.

If the number of device information **702** is 0, then there are no devices **102** contained in the device graph **502** so there is also no device cluster **407**.

The device information **702** includes one or more sensor information **703**, and these sensor information **703** are concentrated in the device information **702**. The sensor information **703** shows the sensor **104** connected to the device information **702**. The sensor information **703** also includes 0 or one or more time-series data **704**, and this time-series data **704** is concentrated in the sensor information **703**. The time-series data **704** includes observation values that were measured by the sensor **104**.

FIG. **8** is a descriptive drawing showing the data structure of the device information **702** and the sensor information **703** in the first embodiment of the present invention.

The device information **702** and the sensor information **703** both include data structures shown in the instance information **801**. The instance information **801** contains an ID**802**, a schema ID**803**, an attribute **804**, and a relation **807**. The ID**802** is an identifier showing a unique device **102** or the pipe **103**, or the sensor **104**. In the following description, the ID**802** corresponding to the device **102** or pipe **103** is displayed as device ID**802**, the ID**802** corresponding to the sensor **104** is displayed as the sensor ID**802**. The schema ID**803** is an identifier showing the unique applicable schema information **810**.

The attribute **804** includes the attribute name **805** and the attribute value **806**. The attribute name **805** indicates the attribute of the device information **702** or the sensor information **703** and includes for example the name of the device **102** or the pipe **103**, the type of operation, and the installation date, etc. The attribute value **806** shows the corresponding value for the attribute name **805**, and includes for example, pump, rotation, Jan. 1, 2010, etc.

The relation **807** includes the relation name **808** and the relation ID**809**. The relation name **808** shows the relation between the device **102** or the pipe **103** or the sensor **104** indicated by the relation ID**809** and the device **102** or the pipe **103** or the sensor **104** shown by the ID**802**; and for example indicates a "connection" or "inclusion" etc. The relation ID indicates an identifier for another related device **102** or pipe **103**, or indicates an identifier for a connected sensor **104**.

The instance information **801** contains 0 or one or more attributes **804**. The instance information **801** also contains 0 or one or more relations **807**. The relation **807** further contains 0 or one or more relations ID**809**.

The time-series data **704** includes the ID**802**, the time **819**, and the observation value **820**. There are 0 or one or more time-series data **704** present. The ID**802** are concentrated in the ID**802** included in the instance information **801**. The time **819** shows the time that the observation value **820** was measured. The observation value **820** shows the observation value that was measured in the device **102** or the pipe **103**. The time-series data **704** is related to the sensor information **703**.

The schema information **810** includes a schema ID**803**, 0 or one or more attribute schema **812**, and 0 or one or more relation schema **816**. The schema ID**803** is concentrated in the ID**802** contained in the instance information **801**.

The attribute schema **812** includes the attribute name **813**, the data type **814**, and the similarity coefficient **815**. The attribute name **813** is the same as the attribute name **805**, and includes the name of the device **102** or the pipe **103**, the type of operation, and the installation date, etc. The data type **814** shows the data type of the attribute shown in the attribute name **813**. If the attribute name **813** for example is a name of a device **102** or pipe **103**, then the data type **814** shows a character string, and if the attribute name **813** is an installation date then the data type **814** shows a date type.

Beside the above described examples, the attribute name **813** may also include attributes such as the installation position, the production manufacturer's name, the average performance, the need (or not) for calibration (namely corrections), or the calibration period in the case that calibration is required.

The similarity coefficient **815** is a coefficient for evaluating the similarity of each device **102**, each pipe **103**, or each sensor **104**. The similarity coefficient **815** is described in detail later on.

The relation schema **816** contains a relation name **817** and 0 or one or more schema ID**818**. The relation name **817** is the same as the relation name **808** and indicates the type of relation with other devices **102**, pipe **103** or sensors **104**. The schema ID**818** indicates an identifier for the schema information **810** of a device **102**, pipe **103**, or sensor **104** connected to a device **102**, pipe **103**, or sensor **104** corresponding to the schema ID**803**.

If the schema ID**803** for example indicates an identifier for the schema information **810** for the motor, then the schema ID**818** shows an identifier for the schema information **810** for the cable, and the attribute name **817** contains a character string for "connection" showing a connected (state). Also if the schema ID**803** shows for example an identifier for the schema information **810** for the turbine, then the schema ID**818** shows an identifier for the schema information **810** for the pipe, and the attribute name **817** contains a character string for "position separated by 10 centimeters" showing positioning separated by a fixed distance.

The relation schema **816** contains a schema ID**818** showing another schema information **810**, and in the aforementioned example includes the schema ID**818** for a specified pipe.

The device information **702** and the sensor information **703** are stored beforehand by the administrator in an examination server **107**.

FIG. **9** is a descriptive drawing showing a specific example of the device information **702** and sensor information **703** of the first embodiment of the present invention.

The device **102** shown in FIG. **9** is a pump #1 (**102-1**), a motor #2 (**102-2**), and a pump #4 (**102-3**). The pipe **103** is a pipe #3 (**103-1**). The sensor **104** is a sensor #5 (**104-1**), a sensor #6 (**104-2**), a sensor #7 (**104-3**), and a sensor #8 (**104-4**).

The pump #1 (**102-1**) and the pipe #3 (**103-1**) are connected, and the pump #1 (**102-1**) and the motor #2 (**102-2**) are connected. Also, the pipe #3 (**103-1**) and the pump #4 (**102-3**) are connected.

The sensor #6 (**104-2**) is connected to the pump #1 (**102-1**), and the sensor #5 (**104-1**) is connected to the motor #2 (**102-2**). Also, the sensor #7 (**104-3**) is connected to the pipe #3 (**103-1**), and the sensor #8 (**104-4**) is connected to the pump #4 (**102-3**).

The device information **702** corresponding to the pump #1 (**102-1**) is the device information **702-1**. The devices **102** shown in FIG. **9** correspond to each of the device information **702**.

The sensor information **703** corresponding to the sensor #8 (**104-4**) is the sensor information **703-4**. The pipe **103** shown in FIG. **9** corresponds to each of the sensor information **703**. Moreover, the sensor #8 (**104-4**) corresponds to the time-series data **704-4**. The ID**802** for the time-series data **704-4** is the same as the ID**802** shown in the sensor information **703-4**. The sensor information **703** and the time-series data **704** for the pipe **103** correspond to the pipe **103** as described above.

The relation **807** is not shown for the device information **702-1** and the sensor information **703-4** shown in FIG. **9**.

The pump #1 (**102-1**) and pump #4 (**102-3**) correspond to the schema information **810-1** showing the schema information **810** for the same A type pump. In other words, the schema ID**803** for the device information **702-1** of pump #1

(**102-1**), and the schema ID**803** for the device information **702** of pump #4 (**102-3**) both show the schema information **810-1**.

The sensor #5 (**104-1**) and sensor #7 (**104-3**) are both a sensor **104** for measuring the vibration in the motor and the pipe; and correspond to the schema information **810-2** as the schema information **810** for the vibration sensor. Further, the sensor #6 (**104-2**) and the sensor #8 (**104-4**) are both a sensor **104** for measuring the pressure in the pump; and correspond to the schema information **810-3** as the schema information **810** for the pressure sensor.

FIG. **10** is a descriptive drawing showing the structure of the sensor selector unit **404** and the sensor selection rule **408** in the first embodiment of the present invention. The structure shown in FIG. **10** corresponds to step **511** and step **512** shown in FIG. **5**.

The observation values measured by the plural sensors **104** are sent to the sensor selector unit **404** by way of the sensor input unit **401**. The sensor **104** sends the observation values by sending the observation event **1001** containing the observation values for sending, to the sensor selector unit **404**. The sensor ID**802** for each of the sensors s1-S6 are here assigned in advance to each sensor **104**.

The observation event **1001** includes the time **819** when the observation values measured, the sensor ID**802**, and the observation value **820**. The observation event **1001** corresponds to the time-series data **704**. The device cluster **407** includes the sensor selection rule **408** just as already described. The observation event **1001** holds the same data as the time-series data **704**. The examination server **107** stores the observation event **1001** as the time-series data **704** during storing of the observation event **1001** in the RDB**306**.

The sensor selector unit **404** retains an assignment map **1005** for assigning the observation events **101** sent from the sensor **104** according to the device cluster **407**. The assignment map **1005** is a map for linking the sensor ID**802** and the device cluster **501**. The assignment map **1005** may for example be a database that holds a key value structure for utilizing the sensor ID**802** as a key for retaining the plural device cluster ID**501** as values, and moreover contains a hash map structure.

The sensor selection rule **408** includes the input ID**1006** and sensor ID**802**, and assigns an input ID**1006** to the sensor ID**802**. The input ID**1006** is an identifier assigned to the sensor ID**802** for selecting the observation value **820** to input to the function required for the processing, during the processing of the observation value **820** in the observation value processor unit **405**. The sensor selector unit **404** is capable of selecting which observation value **820** for the sensor **104** to set as which input values for the function.

The observation event **1001** sent from the sensor **104** is assigned by way of the sensor selector unit **404** to the device cluster **407** for each sensor ID**802**. The sensor selector unit **404** assigns the input ID**1006** to the observation events **1001** sent by way of the sensor **104** shown by the sensor ID**802** according to the sensor selection rule **408** contained in the device cluster **407**.

Here there are cases when one sensor ID**802** is assigned to plural device clusters ID**501**. In the assignment map **1005**, for example, the observation event **1001** whose sensor ID **802** are "s1", "s2", and "s3" are assigned to the device cluster **407** whose device cluster ID**501** are "r1".

The observation event **1001** whose sensor ID**802** are "s3", "s4", "s5" are assigned to the device cluster **407** whose device cluster ID**501** is "r2". The observation event **1001** whose sensor ID**802** is s3 are therefore assigned to the device cluster **407** whose device cluster ID**501** are r1 and r2. In this case, the sensor selector unit **404** copies the observation event **1001** into two items, and assigns the input ID**1006** to each of the copied observation events **1001**.

FIG. **11**A is a descriptive drawing showing an observation value processing rule **409** of the first embodiment of the present invention.

The observation value processing rule **409** includes an element ID**1102**, an input ID**1006**, a processing function **301** and a processing parameter **1103**. The observation value processing rule **409** is present in each device cluster **407** as already described.

The element ID**1102** is an identifier for identifying the elements contained in the feature vector **1101**. The input ID**1006** is an identifier assigned by the sensor selector unit **404** to the observation event **1001**. The elements contained in the element ID**1102** are hereafter given as the element v1, element v2, . . . , and the element Vn.

The processing function **301** is a function for processing the observation value **820** among the observation events **101**. The processing function **301** shown in FIG. **11**A is shown by way of a character string but the processing function **301** may include formulas, and also include parameters for the readout by the formula. The processing parameter **1103** is a parameter for inputting the function shown by way of the processing function **301**.

Plural inputs ID**1006** are sometimes assigned to the element ID**1102**. This arrangement allows inputting observation values **820** that were measured by plural sensors **104** to the function shown in the processing function **301**.

FIG. **11**B is a descriptive drawing showing an example of processing by the observation value processor unit **405** in the first embodiment of the present invention. The processing shown in FIG. **11**B corresponds to step **513** in FIG. **5**.

In the example shown in FIG. **11**B, the circles along the time axis show the observation events **1001**, and show the observation event **1001** accumulated along the time axis. In the time axis shown in FIG. **11**B, the time is newer towards the right side of the axis. The observation events **1001** accumulated according to the time series are given the collective name of input data **1104**.

The element v1 among the feature vectors **1101**, indicates an input ID**1006** that is i1 for the observation value processing rule **409**, and the processing function **301** shows a "none". The observation value processor unit **405** therefore stores the observation value **820** in the element v1 unchanged, and without processing the observation value **820** in the observation event **1001** where input ID**1006** is i1.

The element v2 among the feature vectors **1101**, indicates an input ID**1006** that is i2 for the observation value processing rule **409**, the processing function **301** shows a "movement average", and the processing parameter **1103** shows "5 seconds". The observation value processor unit **405** therefore calculates an average of observation values **820** over 5 seconds, or in other words, calculates the movement average based on the observation value **820** measured over a five second period by the sensor **104** corresponding to i2. The observation value processor unit **405** then stores the calculated movement average in the element v2.

When the processing parameter **1103** shows "5 seconds", then the observation value **820** utilized for the calculation may also be an observation value **820** for the observation event **1001** received over a five second period by the observation value processor unit **405**. Therefore, even if the processing parameter **1103** shows "5 seconds" this display does not signify that there are five observation events **1001**.

The element v3 among the feature vectors **1101**, indicates an input ID**1006** that is i3 and i4 for the observation value processing rule **409**, and the processing function **301** shows "average". The observation value processor unit **405** therefore calculates the average value for the observation value **820** measured by the sensor **104** corresponding to i3 and the sensor **104** corresponding to i4; or in other words, calculates an average for the observation value **820** per the sensor **104** at that same time. The observation value processor unit **405** then stores the calculated average in the element v3.

The element v4 among the feature vectors **1101**, indicates an input ID**1006** that is i5 for the observation value processing rule **409**, and the processing function **301** shows "frequency analysis", and the processing parameter **1103** shows "5 second FFT, A point".

The observation value processor unit **405** therefore makes an FFT (Fast Fourier Transform) or in other words performs a frequency analysis based on the observation value **820** measured over a five second period by the sensor **104** corresponding to i5. Moreover, the "A point" indicates an optional frequency, and among the results **1105** obtained by frequency analysis, the amplitude **1106** for the A point is stored in the element v4.

The processing function **301** for the element v5 among the feature vector **1101** and element v6 among the feature vector **1101** also indicates "frequency analysis" for the observation value processing rule **409**, and the processing parameter **1103** shows "5 second FFT" the same as the feature vector **1101** showing "v4". However, a "B point" is also included in the processing parameter **1103** in the element v5 per the observation value processing rule **409**; and "C point" is included in the processing parameter **1103** in the element v6 per the observation value processing rule **409**.

The observation value processor unit **405** therefore stores the amplitude **1107** at the B point in element V5 and stores the amplitude **1108** for the C point in the element v6 from among the frequency analysis results **1105** implemented based on the observation value **820** measured over a five second period by the sensor **104** corresponding to i5, and the input data **1104** for i5.

FIG. **12** is a flow chart showing frequency analysis by the observation value processor unit **405** of the first embodiment of the present invention. Detailed information on the frequency analysis in FIG. **11** is described below.

First of all, the observation value processor unit **405** acquires the input data **1104** (step **1211**). The input data **1104** is a plurality of observation events **1001** (time-series data **704**) accumulated on a time-series base in the examination server **107**. The observation value processor unit **405** subdivides the acquired input data **1104** into a frame **1201** at time intervals (5 seconds, in FIG. **11**B) specified by the processing parameter **1103** (step **1212**), and converts each frame **1201** into frequency components by FFT and so on (step **1213**).

The observation value processor unit **405** moreover extracts each frequency amplitude specified by the processing parameter **1103** from among the results **1105** obtained by FFT and so on, and outputs the extracted frequency amplitude as the feature vector **1101**.

The event **1305** of the present embodiment is described next.

FIG. **13**A is a descriptive drawing showing an example of distribution of the event **1305** in the first embodiment of the present invention.

The event **1305** here indicates damage likely to occur in the device **102** or the pipe **103**; or that the device **102** or the pipe **103** is in a normal state. Specifically, the event **1305** shows events such as, "fracture has occurred" or "pressure is rising, creating explosion hazard", or "safe condition", etc.

The example in FIG. **13**A shows how the events **1305** are distributed when there are two elements for the feature vector **1101**. The two elements are shown by the element V1 and the element V2. In the drawing shown in FIG. **13**A, the horizontal axis is the value **1501** for element V1 and the vertical axis is the value **1502** for element V2.

The horizontal axis and vertical axis shown in FIG. **13**A are each feature spaces or in other words are dimensions. The feature spaces in the present embodiment are the same in number as the number of feature vector **1101** elements.

The event **1305** is shown in FIG. **13**A by the event A (event **1305-1**), the event B (**1305-2**) and the event C (event **1305-3**).

The event cluster **1308** in FIG. **13**A is the range of values of the feature vector **1101** that the event **1305** occurred in the past and indicates the range of the occurred element V1 value **1501** and element V2 value **1502** judged as extremely likely that the event **1305** occurs.

The event A (event **1305-1**) includes an event cluster **1308** shown by the range c1-c7. The event B (event **1305-2**) includes an event cluster **1308** shown by the range of c8 and c9. The event C (event **1305-3**) includes the event cluster **1308** shown by the range of c10.

The feature vector **1101** value is shown by p1-p3 in FIG. **13**A. If the feature vector **1101** is the p1 contained in the event cluster c2, then in FIG. **13**A there is an extremely high probability that the event A (event **1305-1**) will occur in the device **102** or pipe **103** connected to the sensor **104** corresponding to the feature vector **1101**. If the feature vector **1101** is p2, then in FIG. **13**A there is an extremely high probability that the event B (event **1305-2**) will occur in the device **102** or pipe **103** connected to the sensor **104** corresponding to the feature vector **1101**.

If the feature vector **1101** is p3, then in FIG. **13**A there is a high probability that no event **1305** has occurred in the device **102** or pipe **103** connected to the sensor **104** corresponding to the feature vector **1101**.

The event distance **1503** is the distance between the feature vector **1101** and the center-of-gravity of each event cluster **1308**.

FIG. **13**B is a descriptive drawing showing the relation between the event cluster **1308** and the feature vector **1101** in the first embodiment of the present invention.

The event cluster center-of-gravity **1309** is the center-of-gravity of the event cluster **1308**. The event cluster **1308** is a hyper sphere, or namely is sphere in a multidimensional feature space. The event cluster radius **1310** is the radius of the event cluster **1308** whose center is the event cluster center-of-gravity **1309**.

The distance between the event cluster center-of-gravity **1309** and the feature vector **1101** is the same as the event distance **1503** that was already described. The closer that the feature vector **1101** approached the center-of-gravity of the event cluster **1308**, the higher the probability that the event **1305** corresponding to the event cluster **1308** will occur in the device **102** or the pipe **103** connected to the sensor **104** corresponding to the feature vector **1101**.

FIG. **13**C is a descriptive drawing showing the (math) function for calculating the reliability **1302** in the first embodiment of the present invention.

The reliability **1302** shows the possibility that no event **1305** will occur. The reliability **1302** is calculated by dividing the event distance **1503** by the event cluster radius **1310**. The larger the value of the event distance **1503** and the smaller the value of the event cluster radius **1310**, the higher the reliability **1302** value becomes, and the higher the possibility that no event **1305** will occur.

Also, the lower the value of the event distance **1503** and the higher the value of the event cluster radius **1310**, the smaller the reliability **1302** value becomes, and the lower the possibility that the event cluster **1308** will occur. In other words, the event distance **1503** becomes smaller than the event cluster radius **1310**, and if the reliability **1302** becomes a value lower than 1, then there is a high possibility that the event **1305** will occur.

Conversely, the higher the event cluster radius **1310**, and the lower the event distance **1503**, the lower the reliability **1302** value becomes. The smaller the reliability **1302** value the higher the possibility that the event cluster **1308** will occur.

FIG. **14** is descriptive drawing showing the input/output data for VQC by the examination unit **406** of the first embodiment of the present invention.

The feature vector **1101** generated by the observation value processor unit **405** is sent to the examination unit **406**. The examination unit **406** generates an examination results **1300** by utilizing the codebook **410** contained in the feature vector **1101**, and the device cluster **407**.

The examination results **1300** include the event ID**1301**, the reliability **1302**, and the contribution rate **1303**. The event ID**1301** is an identifier showing the unique event **1305**. The reliability **1302** is the possibility calculated by using the formula shown in FIG. **13**C, and the event **1305** shown by the event ID**1301** might not occur in the device **102** or the pipe **103** connected to the sensor **104** corresponding to the feature vector **1101**.

The contribution rate **1303** contained (contribution rate **1303-1** through contribution rate **1303-***n*) in each element of the feature vector **1101** is a numerical value showing the extent of the contribution the elements apply to the examination results **1300**.

The contribution rate **1303** is found by calculating each of the distance between the each element contained in the feature vector **1101**, and the center-of-gravity of the event **1305**; and then calculating the percent that the calculated distances between the center-of-gravity of event **1305** and each element occupies in the total sum of the distance between the event **1305** center-of-gravity and all elements. The contribution rate **1303** may also be standardized so that summing all of the contribution rates **1303** attains a 1.

The feature vector **1101** for p3 shown in FIG. **13**A is contained in the event cluster **1308** in the value for element V1 but is not contained in the event cluster **1308** in the value for element V2. Therefore when calculating the examination results **1300**, the element V2 contributes more to the examination results **1300** so that the contribution rate **1303** is high.

The code book **410** includes the event set **1304**, the event **1305**, the event cluster **1308** and the event cluster center-of-gravity **1309**. The event set **1304** includes 0 or one or more events **1305**. The code book **410** contains information placed in advance relating to the event **1305**.

The event **1305** includes the event **1131301** and the event cluster set **1307**. The event **1305** includes 0 or one or more event clusters **1308**.

The event cluster **1308** includes the event cluster center-of-gravity **1309** and the event cluster radius **1310**. The event cluster **1308** includes 0 or one or more event cluster center-of-gravity **1309**.

The event cluster center-of-gravity **1309** includes the center-of-gravity (position) **1311**. The event cluster center-of-gravity **1309** includes a number (quantity) of elements for the feature vector **1101**, or namely a number (quantity) of center-of-gravity positions **1311-1** through **1311-***n* for the feature space (dimension).

FIG. **15** is a flow chart showing the VQC by the examination unit **406** of the first embodiment of the present invention.

When the feature vector **1101** is sent from the observation value processor unit **405**, the examination unit **406** stores a numerical value infinity for the nearest distance to initialize (step **1401**). This nearest distance is a parameter. The examination unit **406** then selects one event **1305** from the event **1305** contained in the code book **410** (step **1402**), and selects an event cluster **1308** contained in the event **1305** selected in step **1402** (step **1403**).

The examination unit **406** compares the event cluster center-of-gravity **1309** for the event cluster **1308** selected in step **1403**, with the feature vector **1101** sent from the observation value processor unit **405**, and calculates the distance (step **1404**). The function utilized when calculating the distance is shown below

$$\sqrt{\sum_{t \in All\ attributes} (V_t - C_t)^2} \quad \text{[Formula 1]}$$

Here, Vt is a value for the element of the feature vector **1101**. Also, Ct is a value of the center-of-gravity (position) **1311** for the event cluster **1308**. The t in the formula indicates one element among all of the feature spaces (dimensions) and is a number from 0 to the feature space.

The examination unit **406** then stores the event cluster **1308** with the shortest distance among the calculated distance and the distances calculated up to then into the nearest cluster (step **1405**). The nearest cluster is a parameter. The shortest distance among the distances calculated up to then and step **1404** is stored in the shortest distance (step **1406**).

The examination unit **406** then decides whether or not the distance with all the event clusters **1308** was calculated (step **1407**), and returns to step **1403** if decided the distance with all the event clusters **1308** was not calculated. If the distance for all the event clusters **1308** was calculated then the examination unit **406** decides whether or not the distance for the event clusters **1380** included in all the event **1305** was calculated or not (step **1408**), and returns to step **1402** if decided that the distances for the event clusters **1308** in all of the events **1305** were not calculated.

If decided that the distance for the event clusters **1308** contained in all the event cluster **1305** was calculated, then the examination unit **406** acquires the event ID **1301** contained in the event clusters **1308** shown by the nearest cluster, and stores the acquired event ID **1301** in the event ID **1301** of the examination results **1300** (step **1409**). Then the reliability **1302** is calculated by subtracting the distance calculated in step **1404** from the event cluster **1308** shown by the nearest cluster (step **1410**).

The examination unit **406** further calculates the contribution rate **1303** (step **1411**) based on the feature vector **1101**, the event cluster radius **1310**, and the center-of-gravity position **1311**, and outputs the examination results **1300**.

The above information described the processing up through step **514** in FIG. **5**.

FIG. **16** is a flow chart showing an overview of the processing for generating the device cluster **407** in the first embodiment of the present invention.

The selection rule maker unit **412** generates a new device graph **502** when a new device **102** or pipe **103** has been added to the plant **101** (step **1601**), and generates a sensor selection rule **408** (step **1602**). The processing rule maker unit **413** then generates an observation value processing rule **409** (step **1603**). That examination rule maker unit **414** then generates a code book **410** (step **1604**).

FIG. **17** is a flow chart showing in detail the processing for generating the device cluster **1407** in the first embodiment of the present invention.

If a new device **102** or pipe **103** was added to the plant **101**, then the examination server **107** searches device clusters **407** having a device graph **502** similar to the structure of the new device **102** or pipe **103** (step **1701**). The procedure for searching for a device cluster **407** containing device graph **502** is described later on. The examination server **107** then decides whether or not a similar device cluster **407** was found (step **1702**). If the examination server **107** does not find a similar device cluster **407**, then the administrator inputs a device cluster **407** via the examination server **107** by way of the steps from **1703** onwards.

The administrator makes a device graph **502** based on the design documents (step **1703**), makes a sensor selection rule **408** (step **1705**), makes an observation value processing rule **409** (step **1705**), and inputs each of these rules to the examination server **107**.

The administrator then has the learning unit **304** of examination server **107** learn (step **1706**) the actual events that occurred in specified periods such as a half-year or one year through the usual tasks performed by the new device **102** or pipe **103**. Namely in step **1706**, the learning unit **304** acquires the observation values occurring at specified intervals and learns the contents of the event corresponding to the acquired observation values through entries made by the administrator.

The examination server **107** makes the code book **410** by the learning unit **304** shown in FIG. **3** based on the observation values acquired in step **1706**, and the contents of the events input by the administrator. The examination server **107** then itself inputs the code book **410** that was made in step **1706** (step **1707**).

The examination server **107** then registers (step **1708**) the device cluster **407** by assigning the device clusters ID**501** to each of the information made in the steps **1703**-**1707**.

The examination server **107** then judges whether or not a device cluster **407** was made for all the new devices **102** or pipes **103** (step **1709**). If there are devices **102** or pipes **103** for which a device cluster **407** was not made, then the processing returns to step **1701**. If a device cluster **407** was made for all the new devices **102** or pipes **103** then the processing ends.

The processing from step **1709** onwards may be executed in parallel with the processing from step **1706** since a specified time actually elapses in step **1706**.

When decided in step **1702** that a similar device cluster **407** was found by the examination server **107**, the selection rule maker unit **412** stores the similar device graph **502** for the device cluster **407** found in step **1701**, into the device graph **502** for the device cluster **407** of the new device **102** or the pipe **103** (step **1710**).

The selection rule maker unit **412** further stores the sensor selection rule **408** for the similar device cluster **407** into the sensor selection rule **408** for the device cluster **407** of the new device **102** or pipe **103** (step **1711**). A decision is also made on whether or not all the sensor selection rules **408** corresponding to the device **102** or pipe **103** shown in the device graph **502** were stored (step **1712**) and if there are device graphs **502** in which the sensor selection rules **408** were not stored then the processing returns to step **1711**.

If all of the sensor selection rules **408** corresponding to device **102** or pipe **103** shown in the device graph **502** were stored, then the processing rule maker unit **413** stores the observation value processing rule **409** of the similar device cluster **407** into the observation value processing rule **409** for the device cluster **407** of the new device **102** or pipe **103** (step **1713**). Also a code book **410** for the similar device cluster **407** is stored in the code book **410** of the device cluster **407** of the new device **102** or pipe **103** (step **1714**).

The examination server **107** next decides whether or not correction of the code book **410** stored in step **1714** is required (step **1715**). The examination server **107** decides whether or not correction of the code book **410** is required by way of instructions entered by the administrator. The administrator judges whether or not there are records in the code book **410**, and enters the decision results in the examination server **107**.

When decided in step **1715** that no correction of the code book **410** is needed, the examination server **107** shifts to step **1708**, and registers the device cluster **407**.

If decided in step **1715** that correction of the code book **410** is needed, then the examination server **107** diagnoses the time-series data **704** in cases that occurred in the past by way of the newly generated device cluster **407**. The examination server **107** then outputs the obtained examination results to an output device to allow confirmation by the administrator (step **1716**).

The administrator or other party checks the examination results and decides if relearning is required or not, and inputs information showing whether relearning is necessary or not to the examination server **107**.

The examination server **107** acquires the information input by the administrator showing whether relearning is necessary or not and decides whether or not changing the device cluster **407** by relearning is needed (step **1717**). If decided in step **1717** that relearning is not necessary then the examination server **107** shifts to step **1708** and registers the device cluster **407**.

If decided in step **1717** that relearning is necessary, then the examination server **107** makes the relearning unit **305** perform the relearning at specified periods such as a half-year or one year (step **1718**). The relearning unit **305** performs the relearning by refreshing the event cluster center-of-gravity **1309** and event cluster radius **1310** based on the event cluster **1305** that occurred in a specified period.

The examination server **107** corrects the code book **410** of the new device cluster **407** based on the results from step **1718** (step **1719**), and shift to step **1708**.

The examination server of the present invention is capable of applying the examination rule for a similar device cluster **407** to the new device cluster **407** by performing step **1710** through step **1719**. Moreover, even more flexible examination rules can be applied to the new device cluster **407** by relearning, etc.

The examination server **107** of the present embodiment searches similar device clusters **407** by way of similar device graphs **502** or in other words, searches the connection relations of similar devices **102** and so on from among existing devices **102**, etc.

In the event of new construction at the plant **101**, or addition of the device **102** or the pipe **103**, then the examination server **107** acquires the device cluster **407** corresponding to devices **102** or pipes **103** having a connection relation similar to the new device **102** or the pipe **103** connection relation, among device clusters **407** corresponding to existing devices **102** or pipes **103**; and generates a device cluster **407** corresponding to the new device **102** or pipe **103** based on the acquired device cluster **407**.

In the following description, the device **102** or pipe **103** are given the collective name of node.

FIG. 18A is a descriptive drawing showing a specific example for acquiring similar device graph 502 in the first embodiment of the present invention.

FIG. 18A shows the case where adding a new node A (nodes A1-A6) to a plant 101 containing the existing node B (nodes B1-B4). When the device graph 502 of the nodes A1-A4 among the added nodes A1-A6 are similar to the device graph 502 of the existing (nodes) B1-B4, a device cluster 407A corresponding to the nodes A1-A6 is generated based on the device cluster 407B containing the device graph 502 of the nodes B1-B4.

FIG. 18B is a descriptive drawing showing the generation of a sensor selection rule 408 in the first embodiment of the present invention.

In step 1701 of FIG. 7, when the device cluster 407 corresponding to the nodes A1-A4 shown in FIG. 18A is searched for a device cluster 407 similar to the device cluster 407 corresponding to existing nodes B1-B4, the selection rule maker unit 412 in step 1711 of FIG. 17, generates a new sensor selection rule 408A based on the sensor selection rule 408B contained in the device cluster 407 searched in the step 1701.

The selection rule maker unit 412 first of all makes a combination of nodes A1-A4, and nodes B1-B4 resembling each of the nodes A1-A4, from the results searched in step 1701. The selection rule maker unit 412 then generates a sensor map 2004 by substituting each node the ID802 of the sensors 104 connected to each node.

The selection rule maker unit 412 further generates a sensor selection rule 408A for the new nodes A1-A4, based on the sensor map 2004 and the sensor selection rule 408B corresponding to the existing nodes B1-B4.

The procedure for acquiring a similar device graph 502 in order to search for a similar device cluster 407 in step 1701 of FIG. 17 is shown next.

FIG. 19 is a flow chart showing the procedure for acquiring a similar device graph 502 in the first embodiment of the present invention.

The processing shown in FIG. 19 is equivalent to step 1701 in FIG. 17. The following description is for an example in the case where the nodes A1-A4 were added as shown in FIG. 18A.

The similar graph search unit 302 contained in the examination server 107 selects one among the new nodes A1-A4 (step 1801) when the new nodes A1-A4 have been added to the plant 101. The node selected in step 1801 is described as node A.

One (node) among the existing nodes B1-B4 is selected an object for evaluation (step 1802). The node selected in step 1802 is described as node B.

After step 1802, the similar node search unit 303 calculates the (degree of) similarity of the node B selected in step 1802 and the node A selected in step 1801 (step 1803). The (degree of) similarity is defined by finding values more than zero and setting the smaller one as similar. The method for calculating the similarity is described later on.

The similar graph search unit 302 then decides (step 1804) whether the (degree of) similarity calculated in step 1803 is at or below a pre-established threshold value. If the calculated similarity is below the threshold value, then the node A and the node B are similar so that the device graph 502 contained in node B is added to the similar device graph (step 1805).

The similar graph search unit 302 stores the similarity calculated in step 1803 in the graph similarity of RDB306 (step 1806). The similar device graph and the graph similarity are a storage region stored in the RDB306.

If the similarity calculated in step 1804 is higher than the threshold value, or after step 1806, then the similar graph search unit 302 decides whether the existing nodes B1-B4 were all selected or not (step 1807). If decided that not all of the existing nodes B1-B4 were selected then the similar graph search unit 302 returns to step 1802.

The similar graph search unit 302 selects node B as a reference for comparing with Node A per the processing through step 1807.

If decided that all of the existing nodes (B1-B4) were selected in step 1807, then the similar graph search unit 302 selects one existing device graph 502 as an object for evaluation among similar device graphs added in step 1805 (step 1808). The similar graph search unit 302 then calculates the similarity of the device graph 502 by utilizing the subroutine X (step 1809).

The similar graph search unit 302 decides whether or not the similarity of the device graph 502 calculated in step 1809 is above a threshold value (step 1810). If the similarity of the device graph 502 calculated in step 1809 is higher than the threshold value then the similar graph search unit 302 deletes the device graph 502 selected in step 1808 from the similar device graphs (step 1811) since the device graph 502 selected in step 1808 has no similarity.

If the similarity of the device graph 502 calculated in step 1810 is lower than the threshold value, or after step 1811, then the similar graph search unit 302 outputs the device graph 502 candidate stored in the similar device graph (step 1813). If plural device graphs 502 were stored in the similar device graph, then all of the device graphs 502 are output and the administrator may also select a device graph 502.

The similar graph search unit 302 then outputs the device cluster 407 contained in the device graph 502 having the smallest (degree of) similarity as a similar device cluster for processing in step 1701 of FIG. 17. When a similarity is 0, or namely when the comparison source and the comparison target device clusters are a complete match, a code book correction is not required so that the steps 1715-1719 in FIG. 17 are omitted and the branch can be set for shifting from step 1714 to step 1708. However when the similarity is greater than 0, or namely when the comparison source and the comparison target device clusters do not match, the device clusters are judged similar so that the threshold value is set and the applicable threshold value can be set beforehand by the user in the previously described similar graph search unit 302. However, when the output results in the device cluster processed by the similar graph search unit 302 were judged as unnecessary in step 1717 from results in an abnormal decision check from a past case previously described in step 1716 of FIG. 17, then the similarity of the device cluster when this (relearning) was judged unnecessary is substituted with a threshold value set beforehand by the user so that the similarity threshold value can also be set automatically. This automatic setting allows reducing the number of man-hours for optimizing of the user threshold value settings, and can also enhance an optimized objectivity or reproducibility. Moreover this automatic setting also allows extracting a device cluster not requiring relearning and the similarity is small at the step 1701 stage, so that the processing is speeded up by avoiding the relearning step.

A similar device graph 502 is acquired by way of the processing shown in FIG. 19, and a device cluster 407 corresponding to the acquired device graph 502 serves as the search results in step 1701.

FIG. 20 is a flow chart showing the method for calculating the similarity of the device graphs 502 in the first embodiment of the present invention. The processing shown in FIG. **20** is equivalent to step **1809** in FIG. **19**.

The similar graph search unit **302** selects the node A adjacent to the node A selected in step **1801** of FIG. **19** (step **1901**). The similar graph search unit **302** decides if there is an adjacent node A in step **1801** or not (step **1902**), and if there is no adjacent node A, then the similar graph search unit **302** ends the processing of subroutine X.

If there is an adjacent node A in step **1801**, then the similar graph search unit **302** selects the node corresponding to the device graph **502** selected in step **1802**, or in other words selects a node adjacent to the node B selected in step **1802** (step **1903**).

For example if the similarity of the node A1 selected in step **1801** in FIG. **19** and the node B1 selected in step **1802** is lower than the threshold value, and if the device graph **502** contained in node B1 in step **1808** is selected in step **1903**, the similar graph search unit **302** then selects node B2 adjacent to node B1 shown in FIG. **18**A.

Next, the similar node search unit **303** calculates the similarity between the node A selected in step **1901** and node B selected in step **1903** (step **1904**). The method for calculating the node similarity is described later on.

If the node A selected in step **1901** is for example node A2 shown in FIG. **18**A, and node B selected in step **1903** is the node B2 shown in FIG. **18**A, then the similar graph search unit **302** calculates the similarity of node A2 and node B2 in step **1904**.

After step **1904**, the similar graph search unit **302** then decides whether or not all nodes adjacent to node B selected in step **1802** were selected (step **1905**). If all the nodes adjacent to node B were not selected then the similar graph search unit **302** returns to step **1903**. If all the nodes adjacent to node B were selected, then the similar graph search unit **302** shifts to step **1906**.

When the node B selected in step **1903** for example was the node B2 shown in FIG. **18**A, then there is no other adjacent node to node B1 so that the similar graph search unit **302** decides that all nodes adjacent to node B1 were selected in step **1905**.

The similar graph search unit **302** then adds the similarity of all adjacent nodes calculated in step **1904**, and further adds this summed adjacent node similarity to the similarity of device graph **502** to refresh the similarity of the device graph **502** (step **1906**).

When step **1906** is complete, the similar graph search unit **302** recursively calls up the subroutine X (step **1907**) in order to also perform the processing on the node B selected in step **1903** same as the adjacent nodes. The similar graph search unit **302** stores the node A selected in **1901**, and the node B with the smallest value among the similarities calculated in step **1094**, and executes the recursively called subroutine X based on the stored node information.

If for example the node A selected in step **1901** was the node A2 shown in FIG. **18**A; and the node B with the smallest value of similarity calculated in step **1904** was the node B2; then the similar graph search unit **302** selects the node A3 as the node A adjacent to node A2, in the recursive call subroutine X of step **1901**. The similar graph search unit **302** selects the node B3 connected to node B2 in recursively called subroutine X in step **1903**.

The similar graph search unit **302** searches for a node similar to the newly added node from the existing nodes, and acquires the device graph **502** corresponding to the similar node by the procedure shown in FIG. **19** and FIG. **20**.

FIG. **21** is a flow chart showing the procedure for calculating the similarity of the nodes in the first embodiment of the present invention. The processing in FIG. **21** is identical to the processing in step **1803** of FIG. **19** and step **1904** in FIG. **20**.

The similar node search unit **303** refers to the device information **702** for node A and node B when a new node A and existing node B were selected in step **1802** or step **1903**. The similar node search unit **303** then selects an attribute **804** matching each of the attribute names **805** among the device information **702** for node A and node B (step **2101**).

Next, the similar node search unit **303** decides if the data type **814** for the attribute **804** selected in step **2101** is a numerical value or a character string based on the schema information **810** (step **2102**). If the data type **814** for the selected attribute **804** is a numerical value, and the attribute value **806** for node A and the attribute value **806** for node B can be mutually calculated, then the similar node search unit **303** calculates the attribute distance for node A and node B based on the attribute value **806** of the selected attribute **804** (step **2103**).

Here, the attribute distance is a parameter quantitatively showing the difference between the two nodes.

If the data type **814** for the selected attribute **804** is a character string, and calculating among the attributes **806** is impossible, then the similar node search unit **303** decides if the attribute value **806** of node A and attribute value **806** of the selected node B are a match or not (step **2104**). If the attribute value **806** of the selected node A and the attribute value **806** of node B are a match, then the similar node search unit **303** sets the attribute distance of the node A and node B to 0 (step **2105**). If the attribute value **806** of the selected node A and the attribute value **806** of node B do not match, then the similar node search unit **303** sets the attribute distance between node A and node B to infinity (step **2106**).

After performing step **2103**, step **2105**, or step **2106**, the similar node search unit **303** multiplies the attribute distance between node A and node B calculated in step **2103**, step **2105**, or step **2106**, by the similarity coefficient **815** decided beforehand according to the attribute name **805** (step **2107**).

The similar node search unit **303** also refreshes the node similarity by using the value calculated in step **2107** (step **2108**). In other words, the similar node search unit **303** calculates the node similarity by way of the following formula (2) using the attribute distance between the nodes and the similarity coefficient **815**.

$$\sum_{i \in All\ attributes} k_i \cdot (a_i - b_i)^2 \quad \text{[Formula 2]}$$

The k in formula 2 denotes the similarity coefficient **815**, which is established beforehand for each attribute. The a_i denotes a new node attribute value, and b_i denotes an existing node attribute value. The node similarity is calculated by finding the sum of multipliers obtained from the square of the difference between a_i and b_i times the similarity coefficient **815** for all attributes. The similarity coefficient **815** is stored in the schema information **810**.

The similar node search unit **303** decides if the attribute distance and the node similarity were calculated for all attributes or not, and if all attributes were not calculated, returns to step **2101**. If all attributes were calculated, then the similar node search unit **303** outputs the sum of the node similarities (step **2110**), and the similarity calculation procedure then ends.

The processing shown in FIG. **21** calculated the node similarity however the sum of the node similarity is the similarity of the device graph **502**. Moreover, the similarity of the device graph **502** is the similarity among the device clusters **407** or namely is the distance of the device clusters **407**. The sum of the node similarity hereafter indicates the same meaning as the distance of the device clusters **407**.

FIG. **22** is a descriptive drawing showing a specific example of calculating the attribute distance in the first embodiment of the present invention.

The attribute **804** of node A selected in step **1801** of FIG. **19** or step **1901** of FIG. **20** is shown as attribute **804**A-**1**. Also, the attribute **804** of each node B selected from the existing node B in step **1802** or step **1903** is shown as the attributes **804**B-**1** through attribute **804**B-**4**.

The attribute **804**A-**1** includes the attribute **804**A-**1**-**1**, attribute **804**A-**1**-**2**, and the attribute **804**A-**1**-**3**. The attribute **804**A-**1**-**1** has "device type" as the attribute name **805**; and "pump" as the attribute value **806**. The attribute **804**A-**1**-**2** has "sensor type" as the attribute name **805**; and "vibration" as the attribute value **806**. The attribute **804**A-**1**-**3** has "years used" as the attribute name **805**; and "2 years" as the attribute value **806**.

The attribute **804**B-**1** includes the attribute **804**B-**1**-**1** and the attribute **804**B-**1**-**2**. The attribute **804**B-**1**-**1** has "device type" as the attribute name **805**; and "motor" as the attribute value **806**. The attribute **804**B-**1**-**2** has "sensor type" as the attribute name **805**; and "vibration" as the attribute value **806**.

The attribute **804**B-**2** includes the attribute **804**B-**2**-**1** and the attribute **804**B-**2**-**2**. The attribute **804**B-**2**-**1** has "device type" as the attribute name **805**; and "pump" as the attribute value **806**. The attribute **804**B-**2**-**2** has "sensor type" as the attribute name **805**; and "pressure" as the attribute value **806**.

The attribute **804**B-**3** includes the attribute **804**B-**3**-**1**, the attribute **804**B-**3**-**2**, and the attribute **804**B-**3**-**3**. The attribute **804**B-**3**-**1** has "device type" as the attribute name **805**; and "pump" as the attribute value **806**. The attribute **804**B-**3**-**2** has "sensor type" as the attribute name **805**; and "vibration" as the attribute value **806**. The attribute **804**B-**3**-**3** has "years used" as the attribute name **805**; and "10 years" as the attribute value **806**.

The attribute **804**B-**4** includes the attribute **804**B-**4**-**1**, the attribute **804**B-**4**-**2**, and the attribute **804**B-**4**-**3**. The attribute **804**B-**4**-**1** has "device type" as the attribute name **805**; and "pump" as the attribute value **806**. The attribute **804**B-**4**-**2** has "sensor type" as the attribute name **805**; and "vibration" as the attribute value **806**. The attribute **804**B-**4**-**3** has "years used" as the attribute name **805**; and "1 year" as the attribute value **806**.

When the attribute **804**A-**1**-**1** and the attribute **804**B-**1**-**1** were selected in step **2101** of FIG. **21**, the attribute **804**A-**1**-**1** and the attribute **804**B-**1**-**1** both have character strings as the data type **814** so that a decision is made on whether the attribute values **806** are a match or not. These attribute values **806** are respectively a "pump" and "motor" and so are decided as a mismatch, and infinity is stored in the attribute distance.

Here, when the similarity coefficient **815** whose attribute **804** is "device type" and is not 0, the similarity of the device cluster **407** calculated in step **2110** becomes infinity.

When the attribute **804**A-**1**-**1** and the attribute **804**B-**2**-**1** were selected in step **2101** of FIG. **21**, the attribute values **806** of the attribute **804**A-**1**-**1** and the attribute **804**B-**2**-**1** are both the same so that a "0" is stored in the attribute distance. Further, when the attribute **804**A-**1**-**2** and the attribute **804**B-**2**-**2** were selected, the attribute value **806** of the attribute **804**A-**1**-**2** is "vibration", and the attribute value **806** of the attribute **804**B-**2**-**2** is "pressure" so that the attribute are decided as a mismatch in step **2104**, and infinity is stored in the attribute distance.

When the attribute **804**A-**1**-**1** and the attribute **804**B-**3**-**1** were selected in step **2101** of FIG. **21**, the attribute value **806** of the attribute **804**A-**1**-**1** and the attribute **804**B-**3**-**1** are the same so that a "0" is stored in the attribute distance. The attributes **804**A-**1**-**2** and the attribute **804**B-**3**-**2** likewise, both have the same attribute values **806** for the attribute **804**A-**1**-**2** and the attribute **804**B-**3**-**2** are the same so that a "0" is stored in the attribute distance.

When the attribute **804**A-**1**-**3** and the attribute **804**B-**3**-**3** were selected in step **2101** of FIG. **21**, the attribute **804**A-**1**-**3** and the attribute **804**B-**3**-**3** both have numerical value as the data type **814** so that the attribute distance is calculated. The attribute value **806** of the attribute **804**A-**1**-**3** is "2 years", and the attribute value **806** of the attribute **804**B-**3**-**3** is "10 years" so that the attribute distance is calculated as $|2-10|=8$.

When the attribute **804**A-**1**-**1** and the attribute **804**B-**4**-**1** were selected in step **2101** of FIG. **21**, the attribute values **806** of the attribute **804**A-**1**-**1** and the attribute **804**B-**4**-**1** are both the same so that a "0" is stored in the attribute distance. The attribute **804**A-**1**-**2** and the attribute **804**B-**4**-**2** likewise, both have the same attribute value **806** for the attribute **804**A-**1**-**2** and the attribute **804**B-**4**-**2** so that a "0" is stored in the attribute distance.

When the attribute **804**A-**1**-**3** and the attribute **804**B-**4**-**3** were selected in step **2101** of FIG. **21**, the attribute **804**A-**1**-**3** and the attribute **804**B-**4**-**3** both have numerical value as the data type **814** so that the attribute distance is calculated. The attribute value **806** of the attribute **804**A-**1**-**3** is "2 years", and the attribute value **806** of the attribute **804**B-**4**-**3** is "1 year" so that the attribute distance is calculated as $|2-1|=1$.

The attribute distance in the present embodiment is calculated as previously described. The calculated attribute distance is multiple by the similarity coefficient **815**, and added to the similarity of the device cluster **407**. If the attribute values **806** are a match, then a "0" was stored in the attribute distance, however any value that is as small as possible but is not "0" may be stored. The administrator can in this way calculated the node similarity so that a more important attribute **804** can be selected.

The procedure for calculating the similarity coefficient **815** is shown next.

FIG. **23** is a flow chart showing the procedure for calculating the similarity coefficient **815** in the first embodiment of the present invention.

First of all, the similar node search unit **303** calculates the distance of the event cluster **1308** corresponding to each device cluster **407** (step **2301**). Here, when there are N number of similarity coefficients **815** to calculate, the sum total of volumes in the device cluster **407** contained in the attribute **804** corresponding to similarity coefficient **815**; and also in the dimension of the corresponding event cluster **1308** is shown by Si (i=0 through N).

Device clusters **407** equal in number to the attributes **804** corresponding to the similarity coefficient **815**, and one device cluster **407** serving as the reference for calculating the similarity coefficient **815** are selected beforehand for the device cluster **407** utilized for calculating the similarity coefficient **815**.

The "dimension" for the total sum of volume Si in the dimension of event cluster **1308** is the number of elements V shown in the FIG. **13**A corresponding to the event cluster **1308**. The "dimensional volume" shows the volumetric range to distribute the event cluster **1308** in each dimension. The "sum total" is the value from summing all the volumes of each event cluster **1308** because there are plural event clusters **1308** for each event **1305**.

Here, S0 is the sum total of the volume in the dimension of the event cluster **1308** corresponding to the device cluster **407** serving as a reference for calculating the similarity coefficient **815**. The event cluster **1308** distance is defined by the formula 3 shown below.

$$\frac{|S_i - S_0|}{|S_0|} \quad \text{[Formula 3]}$$

Here, |Si−S0| is the difference between the sum total of the volumes of the event cluster **1308**. Formula 3 is used to calculate the percentage that the difference between the sum total of the volumes of the event cluster **1308** as an object for comparison and the sum total of the volumes of the event cluster **1308** serving as a reference, occupies in the sum total of the volumes of the event cluster **1308** serving as the reference, and those calculated results then define the distance of the event cluster **1308**.

The similar node search unit **303** calculates the distance of the event cluster **1308** by way of the formula 3.

Here, when the distance of the event cluster **1308** and the distance of the device cluster **407** are equal, then the following calculation can be made using formula 1 and formula 3.

$$\begin{bmatrix} (b_{11}-a_{01})^2 & \dots & (b_{1N}-a_{0N})^2 \\ \vdots & \ddots & \vdots \\ (b_{N1}-a_{01})^2 & \dots & (b_{NN}-a_{0N})^2 \end{bmatrix} \begin{bmatrix} k_1 \\ \vdots \\ k_N \end{bmatrix} = \frac{1}{|S_0|} \begin{bmatrix} |S_1 - S_0| \\ \vdots \\ |S_N - S_0| \end{bmatrix} \quad \text{[Formula 4]}$$

Here, aji denotes the value for attribute **804** contained in the device cluster **407** serving as the reference, and bji denotes the attribute **804** contained in the device cluster **407** serving as the object for comparison. The i denotes the number of similarity coefficients **815** for calculation as previously described or in other words is the number of attributes **804**. The j is the number of device clusters **407** serving as the object for comparison or in other words is the number of similarity coefficients **815** for calculation.

The first term on the left side is an expression describing the distance of the device cluster **407** by way of a matrix. The right side is an expression showing the distance of the event cluster **1308** calculated in step **2301** by way of a matrix.

The similar node search unit **303** calculates the matrix showing the distance of the device cluster **407** (step **2302**). The similar node search unit **303** further calculates the value for ki serving as the similarity coefficient **815** by calculating the inverse matrix on the left side of formula 4 (step **2303**). The similar node search unit **303** then outputs the calculated value for the similarity coefficient **815** (step **2304**).

The similarity coefficient **815** is therefore calculated as described above.

FIG. **24**A is a descriptive drawing showing an example of the distance of the device cluster **407** in the first embodiment of the present invention.

The Table **2041** is a table showing the distance of the device clusters C0-C3 (**407**) utilizing the attribute **804** of the nodes contained in each of the device cluster C0 (**407**), device cluster C1 (**407**), and the device cluster C2 (**407**). The horizontal axis in Table **2401** is the frequency of usage, and the vertical axis is the years used. The vertical axis and the horizontal axis in Table **2401** correspond to the attribute name **805**.

The attribute **804-00** for the node contained in the device cluster C0 (**407**) has 2 years as the used years, and 10 times per year as the frequency of usage. The attribute **804-01** for the node contained in device cluster C1 (**407**) has 10 years as the used years, and 20 times per year as the frequency of usage. The attribute **804-02** for the node contained the device cluster C2 (**407**) has 1 year as the used years, and 80 times per year as the usage frequency.

In the similarity coefficient **815** for the years used are shown by k1, and the frequency of usage for the similarity coefficient **815** is shown by k2.

When using the device cluster C0 (**407**) as a reference, the distance for device cluster C1 (**407**) is k1 (2−10) 2+k2 (10−20)2; and the distance for the device cluster C2 (**407**) is k1 (2−1)2+k2 (10−80)2.

FIG. **24**B is a descriptive drawing showing an example of the distance of the event cluster **1308** in the first embodiment of the present invention.

The event cluster **1308** of device cluster C0 (**407**) is plural true spheres shown by the event clusters **1308-00** in FIG. **24**B. The event cluster **1308** of device cluster C1 (**407**) is plural true spheres shown by the event clusters **1308-01**. The event cluster **1308** of device cluster C2 (**407**) is plural true spheres shown by the event clusters **1308-02** in FIG. **24**B.

The sum total of the volume of the true spheres of the event cluster **1308-00** is shown by S0, the sum total of the volume of the true spheres of the event cluster **1308-01** is shown by S1, and the sum total of the volume of the true spheres of the event cluster **1308-02** is shown by S2.

The distance of the event cluster **1308** between the device cluster C0 (**407**) and the device cluster C1 (**407**) by way of the above described formula 3 is shown by |S1−S0|/|S0|. The event clusters **1308-00** and the event clusters **1308-1** shown in FIG. **24**B mostly overlap so that the value of |S1−S0| is smaller than |S0|. The |S1−S0|/|S0| is therefore a value smaller than 1.

The distance of the event cluster **1308** between the device cluster C0 (**407**) and device cluster C2 (**407**) on the other hand is shown by |S2−S0|/|S0|. The event cluster **1308-00** and the event cluster **1380-02** shown in FIG. **24**B do not overlap so that the |S2−S0|/|S0| is a value larger than 1.

Utilizing the distance for the event cluster **1308**, and the device cluster **407** calculated as described above allows establishing the simultaneous equation as shown below.

$$k1(2-10)^2+k2(10-20)^2=|S1-S0|/|S0|$$

$$k1(2-1)^2+k2(10-80)^2=|S2-S0|/|S0| \quad \text{[Formula 5]}$$

If the value for |S1−S0|/|S0| is set as 0.1, and the value for |S2−S0|/|S0| is set as 2, then the value for k1 is calculated as 9.3e-4 (logarithmic notation), the value for k2 as 4.1e-4.

The first embodiment renders the effect that the man-hours required for setting examination rules can be reduced, and that examination rules for the new device **102** or pipe **103** can be set at an early stage, even if a new device **102** or pipe **103** was added, by applying an existing device cluster **407** to the new device **102** or pipe **103** having a structure similar to an existing device **102** or pipe **103**.

Second Embodiment

FIG. **25** is a descriptive drawing showing an example of applying a device cluster **407** to a new plant **101** in the second embodiment of the present invention.

As can be seen in FIG. **25**, the existing plant **101**A contains the device or pipes m21-m26; and the new plant **101**B contains the device or pipes m27-m35.

In the present invention, when a plant **101**B was added to an existing plant **101**A, and a device cluster **407**E and device cluster **407**F were set in the existing plant **101**A, the device cluster **407**E and device cluster **407**F are applied to the device **102** or pipe **103** contained in the newly added plant **101**B.

A device combination having a device graph **502** similar to the device graph **502** for m21-m23 is extracted from the new plant **101**B, and applies the device cluster **407**E for the devices or pipes m21-m23 to this extracted device combination. The device cluster **407**G and device cluster **407**H are in this way generated in the device or pipes m27-m29 and m30-m32 as shown in the example in FIG. **25**.

A device combination having a device graph **502** similar to the device graph **502** of the devices or pipes m24-m26 is also extracted from the new plant **101**B, and applies the device cluster **407**I for the device or pipe m24-m26 to this extracted device combination. The device cluster **407**I are in this way generated in the device or pipes m33-35 as shown in the example in FIG. **25**.

Therefore, even if a new plant **101**B was added, the second embodiment is capable or reducing the number of required user man-hours and setting the examination rules at an early stage in the plant **101**B by applying the device cluster **407** contained in the existing plant **101**A.

The present embodiment was described above in detail while referring to the accompanying drawings however the present invention is not limited to these types of specific structures and may also include all manner of changes and equivalent structures that fall within the range of the appended claims.

The invention claimed is:

1. A computer system, comprising:

a plurality of sensors mounted in a plurality of devices to measure specified physical quantities; and

a server configured to examine the physical quantities sent from the sensors,

wherein the devices are classified into a first device group, and a plurality of second device groups,

wherein the second device groups include a plurality of second examination rules showing examination methods for the physical quantities,

wherein the server includes a storage device,

wherein the server is configured to store, in the storage device, an attribute which indicates types of the plurality of devices and types of the physical quantities measured by the sensors, and store sensor information of devices, the sensor information including an attribute value of the attribute, regarding the first device group and the second device groups,

wherein the server is configured to store, in the storage device, examination information indicating the second examination rules included in the second device groups,

wherein the server is configured to calculate a similarity coefficient of the attribute,

wherein the server is configured to calculate, by using the sensor information, similarities between each device in the first device group and each device in the second device group, by obtaining multipliers from the calculated similarity coefficient of the attribute and an attribute distance for each attribute and summing the obtained multipliers, the attribute distance being calculated based on the difference between an attribute value of each device in the first device group and an attribute value of each device in the second device groups,

wherein the server is configured to calculate a similarity between the first device group and each of the second device groups based on the similarities between each device in the first device group and each device in the second device groups, and

wherein the server is configured to extract a first examination rule to be set in the first device group from the second examination rules, which are indicated by the examination information and set in the second device groups, on the calculated similarity between the first device group and each of the second device groups.

2. The computer system according to claim **1**, wherein the server is configured to:

group the plurality of second device groups into a reference device group and a comparison device group,

calculate a percentage that the difference between a sum total of volumes of an event cluster calculated based on physical quantities which a sensor of the comparison device group measures, and a sum total of volumes of an event cluster calculated based on physical quantities which a sensor of the reference device group measures, occupies in the sum total of the volumes of the event cluster calculated based on the physical quantities which the sensor of the reference device group measures, and

calculate a similarity coefficient for each attribute based on the calculated percentage and the attribute value included in the sensor information.

3. The computer system according to claim **2**, wherein the server is configured to:

select a first device from the first device group,

select a second device from the second device groups,

calculate a similarity between the first device group and the second device groups when a similarity between the first device and the second device is below a first specified threshold,

search for one of the second device groups such that a calculated similarity between the first device group and the one second device group is lower than a second specified threshold from the second device groups, and

extract the first examination rule to be set in the first device group from the second examination rule set in the one second device group.

4. The computer system according to claim **2**, wherein the server is configured to:

select a third device adjacent to the first device in the first device group,

select a fourth device, when there is a fourth device adjacent to the second device in the second device group, and

calculate a similarity between the third device and the fourth device based on the sensor information of devices,

select a fifth device adjacent to the third device in the first device group,

select a sixth device, when there is a sixth device adjacent to the fourth device in the second device groups,

calculate a similarity between the fifth device and the sixth device based on the sensor information of devices, and

calculate a similarity between the first device group and each of the second device groups by summing the similarity between the first device and the second device, the similarity between the third device and the fourth device, and the similarity between the fifth device and the sixth device.

5. The computer system according to claim **2**, wherein the first and second examination rules contain information relating to an event corresponding to the measured physical quantities,

wherein the server is configured to:

calculate a volume of range of physical quantities having a high possibility of a particular event occurring as a sum total of volumes of an event cluster of the reference device group, based on information relating to the event corresponding to the reference device group, and

calculate a volume of range of physical quantities having a high possibility of another event occurring as a sum total of volumes of an event cluster of the comparison device group, based on information relating to the event corresponding to the comparison device group.

6. The computer system according to claim **1**, further comprising a method for processing the physical quantity set in a device belonging to the second device groups in order to examine the physical quantity,

wherein the server is configured to extract a first method for processing a physical quantity set in the first device group, from a second method for processing a physical quantity set in the second device groups based on the calculated similarity between the first device group and each of the second device groups.

7. The computer system according to claim **1**, wherein the server is configured to:

output an event corresponding to a physical quantity measured by a sensor in a specified period based on information relating to an event contained in the examination rule, and

acquire information indicating whether or not the information relating to the outputted event requires refreshing, and

refresh information relating to the outputted event when refreshing of the information relating to the outputted event is required.

8. The computer system according to claim **7**, wherein the server is configured to:

acquire the physical quantity measured by the sensor in the specified period, and an event that has occurred in the specified period, and

refresh the information relating to the event by way of the acquired physical quantity and event.

9. A rule generation method according to a plurality of sensors installed in a plurality of devices to measure specified physical quantities, and a server configured to examine the physical quantities sent from the sensors,

the devices being grouped into a first device group and a plurality of second device groups, and

the second device groups containing a plurality of second examination rules indicating examination methods for the physical quantities,

the server including a processor and a storage device,

the server being configured to store, in the storage device, an attribute which indicates types of the plurality of devices and types of the physical quantities measured by the sensors, and storing sensor information of devices, the sensor information including an attribute value of the attribute, regarding the first device group and the second device groups,

the server being configured to store, in the storage device, examination information indicating the second examination rules included in the second device groups,

the rule generation method comprising steps of:

calculating, by the processor, a similarity coefficient of the attribute,

calculating, by the processor and by using the sensor information, similarities between each device in the first device group and each device in the plurality of second device groups, by obtaining multipliers from the calculated similarity coefficient of the attribute and an attribute distance for each attribute and summing the obtained multipliers, the attribute distance being calculated based on the difference between an attribute value of each device in the first device group and an attribute value of each device in the second device groups,

calculating, by the processor, a similarity between the first device group and each of the second device groups based on a similarity between each device in the first device group and each device in the second device groups; and

extracting, by the processor, a first examination rule to be set in the first device group from the second examination rules, which are indicated by the examination information and set in the second device groups, based on the calculated similarity between the first device group and each of the second device groups.

10. The rule generation method according to claim **9**, wherein

the calculating the similarity coefficient includes:

grouping, by the processor, the plurality of second device groups into a reference device group and a comparison device group,

calculating, by the processor, a percentage that the difference between a sum total of volumes of an event cluster calculated based on physical quantities which a sensor of the comparison device group measures, and a sum total of volumes of an event cluster calculated based on physical quantities which a sensor of the reference device group measures, occupies in the sum total of the volumes of the event cluster calculated based on the physical quantities which the sensor of the reference device group measures; and

calculating, by the processor, a similarity coefficient for each attribute based on the calculated percentage and the attribute value included in the sensor information of devices;

wherein the calculating the similarities between each device in the first device group and each device in the second device groups includes:

selecting, by the processor, a first device from the first device group,

selecting, by the processor, a second device from the second device groups,

calculating, by the processor, a similarity between the first device group and the second device groups when a similarity between the first device and the second device is below a first specified threshold value,

wherein the extracting the first examination rule includes:

searching, by the processor, for one of the second device groups such that a calculated similarity of the first device group and the one second device group is lower than a second specified threshold from the second device groups, and

extracting, by the processor, the first examination rule to be set in the first device group from the second examination rule set in the one second device group.

11. The rule generation method according to claim **10**, wherein

the calculating the similarities between each device in the first device group and each device in the second device groups includes:

selecting, by the processor, a third device adjacent to the first device in the first device group;

selecting, by the processor, a fourth device when there is a fourth device adjacent to the second devices in the second device group;

calculating, by the processor, a similarity between the third device and the fourth device based on the sensor information of devices;

selecting, by the processor, a fifth device adjacent to the third device in the first device group;

selecting, by the processor, a sixth device when there is a sixth device adjacent to the fourth device in the second device groups;

calculating, by the processor, a similarity between the fifth device and the sixth device based on the sensor information of devices; and

wherein the calculating the similarity between the first device group and each of the second device groups includes:

calculating, by the processor, the similarity between the first device group and each of the second device groups by summing the similarity between the first device and the second device, and the similarity between the third device and the fourth device, and the similarity between the fifth device and the sixth device.

12. The rule generation method according to claim **10**,

wherein the first and second examination rules contain information relating to an event corresponding to a measured physical quantity,

wherein the calculating the similarity coefficient includes:

calculating, by the processor, a volume of range of physical quantities having a high possibility of a particular event occurring as a sum total of volumes of an event cluster of the reference device group, based on information relating to the event corresponding to the reference device group, and

calculating, by the processor, a volume of range of physical quantities having a high possibility of another event occurring as a sum total of volumes of an event cluster of the comparison device group, based on information relating to the event corresponding to the comparison device group.

13. The rule generation method according to claim **9**, wherein a method for processing a physical quantity is set in the second device groups in order to examine the physical quantity; and

the extracting the first examination rule includes:

extracting, by the processor, a first method for processing a physical quantity to be set in the first device group from a second method for processing a physical quantity set in the second device groups, based on the calculated similarity between the first device group and each of the second device groups.

14. The rule generation method according to claim **9**, further comprising:

outputting, by the processor, an event corresponding to a physical quantity measured by a sensor in a specified period, based on information relating to an event contained in the examination rule;

acquiring, by the processor, information indicating whether refreshing of information relating to the event that has been output is required or not;

acquiring, by the processor, an event that has occurred in the specified period, and a physical quantity measured by the sensor in a specified period, when the information relating to the event that has been output must be refreshed; and

refreshing, by the processor, information relating to the event by way of the acquired physical quantity and the event.

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