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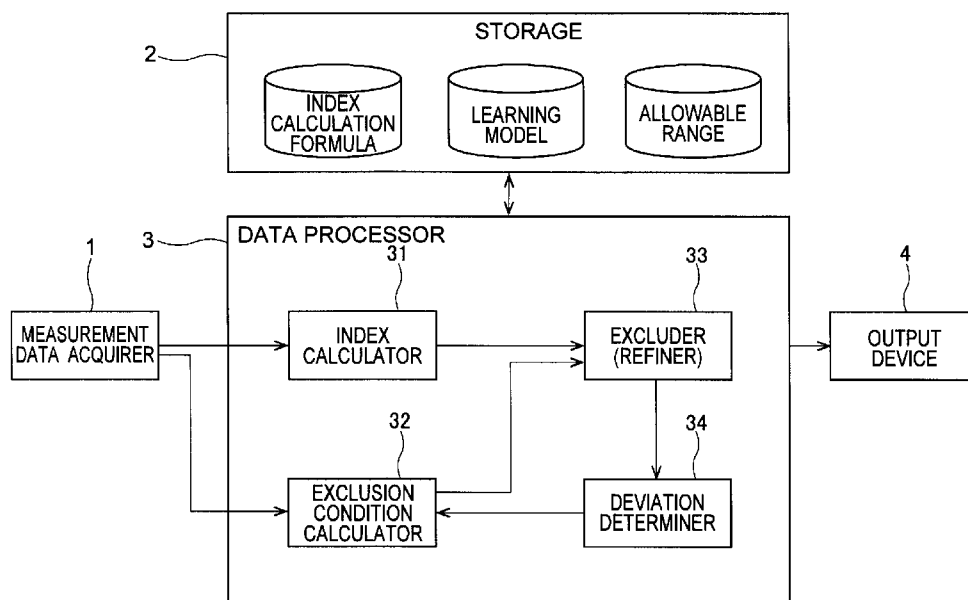
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(54) Title: DATA PROCESSING APPARATUS, DATA PROCESSING METHOD, AND PROGRAM

[Fig. 1]



(57) Abstract: A data processing apparatus as one aspect of the present invention includes an index calculator, an exclusion condition calculator, and a refiner. The index calculator calculates index data containing indices which represent a state of a monitoring target on the basis of measurement data on the monitoring target. The exclusion condition calculator calculates an exclusion condition used to remove any index related to a disturbance from the index data on the basis of the measurement data. The refiner removes the index related to a disturbance from the index data on the basis of the exclusion condition and thereby refines the index data.

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Description

Title of Invention: DATA PROCESSING APPARATUS, DATA PROCESSING METHOD, AND PROGRAM

Field

[0001] An embodiment relates to a data processing apparatus, a data processing method, and program.

Background

[0002] In order to continue operating a system safely and stably, it is essential to inspect soundness of the system and perform maintenance as required. However, the higher the inspection frequency is, the higher the maintenance costs become. Thus, a next inspection plan is worked out on the basis of the elapsed time from the last maintenance, operating hours of the system, and the like. A maintenance method which works out an inspection plan on the basis of time in this way is called TBM (Time Based Maintenance).

[0003] It has been becoming mainstream to grasp a system state in real time with remote monitoring in recent years along with advances in radio technology, cost reductions of sensors, and the like. If a present state of the system can be grasped, an inspection date can be postponed, unnecessary inspection items can be omitted, and so on. A maintenance method which works out an inspection plan on the basis of the present state of the system in this way is called CBM (Condition Based Maintenance). Reduction in maintenance costs is expected by shifting from TBM to CBM.

[0004] However, various disturbances are prone to get into data which is measured to grasp the present state of the system during operation of the system. Thus, in order to grasp the present state of the system with high accuracy, it is necessary to remove unnecessary disturbances from measurement data.

Brief Description of Drawings

[0005] [fig.1]FIG. 1 is a block diagram illustrating an example of a data processing apparatus according to a first embodiment;

[fig.2]FIG. 2 is a diagram describing index data;

[fig.3]FIG. 3 is a diagram illustrating an example of an exclusion condition;

[fig.4]FIG. 4 is a diagram illustrating processing results produced by an excluder and deviation determiner;

[fig.5]FIG. 5 is a diagram illustrating an example of an output produced by an output device;

[fig.6]FIG. 6 is a diagram illustrating an example of a schematic flowchart of an

overall process performed by the data processing apparatus according to the first embodiment;

[fig.7]FIG. 7 is a block diagram illustrating an example of a schematic configuration of a data processing apparatus according to a second embodiment;

[fig.8]FIG. 8 is a diagram describing modification of an exclusion condition;

[fig.9]FIG. 9 is a diagram illustrating an example of a flowchart of an exclusion condition update process;

[fig.10]FIG. 10 is a block diagram illustrating an example of a schematic configuration of a data processing apparatus according to a third embodiment;

[fig.11]FIG. 11 is a diagram illustrating an example of results on counted sample counts;

[fig.12]FIG. 12 is a diagram illustrating another example of results on counted sample counts;

[fig.13]FIG. 13 is a block diagram illustrating an example of a schematic configuration of a data processing apparatus according to a fourth embodiment;

[fig.14]FIG. 14 is a diagram describing evaluation input with respect to state determination;

[fig.15]FIG. 15 is a diagram illustrating an example of a history of correct answers to state determination;

[fig.16]FIG. 16 is a diagram illustrating an example of a flowchart of state determination; and

[fig.17]FIG. 17 is a block diagram illustrating an example of hardware configuration according to one embodiment of the present invention.

DETAILED DESCRIPTION

[0006] One embodiment of the present invention determines any disturbance contained in measurement data on a monitoring target.

[0007] A data processing apparatus as one aspect of the present invention includes an index calculator, an exclusion condition calculator, and a refiner. The index calculator calculates index data containing indices which represent a state of a monitoring target on the basis of measurement data on the monitoring target. The exclusion condition calculator calculates an exclusion condition used to remove any index related to a disturbance from the index data on the basis of the measurement data. The refiner removes the index related to a disturbance from the index data on the basis of the exclusion condition and thereby refines the index data.

[0008] Below, a description is given of embodiments of the present invention with reference to the drawings. The present invention is not limited to the embodiments.
(First Embodiment)

[0009] FIG. 1 is a block diagram illustrating an example of a data processing apparatus

according to a first embodiment. The data processing apparatus according to the first embodiment includes a measurement data acquirer 1, a storage 2, a data processor 3, and an output device 4. The data processor 3 includes an index calculator 31, an exclusion condition calculator 32, an excluder (refiner) 33, and a deviation determiner 34.

[0010] The data processing apparatus according to the present embodiment calculates index data containing an index which represents the state of a monitoring target on the basis of measurement data on the monitoring target. The index is used to detect any abnormality of the monitoring target, determine whether or not the monitoring target needs to be inspected, and so on.

[0011] It is conceivable that the index to be calculated represents a state difficult to measure with a sensor or the like. For example, the index may be one (a performance index) that represents a state of performance of the monitoring target.

[0012] The monitoring target is not specifically limited, and may be a piece of equipment or a system made up of plural device. Also, the monitoring target may be a living body such as a human or animal.

[0013] The measurement data means time series data including measurement results produced by sensors or the like. Measurement results include measurement time, measured values, and the like. Regarding the sensors, well-known sensors may be used.

[0014] Measurement items of the measurement data may be items measurable by well-known sensors or the like. Measurement points may be the entire monitoring target or specific sites of the monitoring target. Examples of possible measurement items include temperature, humidity, flow rate, current, voltage, pressure, and position. Also, when the monitoring target is a movable body such as a vehicle, it is conceivable that the velocity, acceleration, and the like of the movable body will also be included in the measurement items.

[0015] It is assumed that measurements for acquiring measurement data can be taken at any time. Thus, the measurement data can include both data measured when the monitoring target is operating and data measured when the monitoring target is stopped.

[0016] Incidentally, measurement results produced by the monitoring target itself may also be included in the measurement data. Also, settings inputted to the monitoring target may also be included in the measurement data. For example, data representing time periods during which the monitoring target is powered on or off may also be included. For example, if the monitoring target has a power-saving mode to reduce power consumption, data representing time periods during which the monitoring target is in power-saving mode may also be included in the measurement data. For example,

if the monitoring target is an air conditioner, data representing a state such as "cooling," "heating," or "humidifying" may be included in the measurement data. If the monitoring target is a vehicle, data representing a state (such as "running," "accelerating," "decelerating," and "stopped temporarily") may be included in the measurement data.

[0017] The measurement data may also include the state of the monitoring target determined by the monitoring target itself or another external apparatus on the basis of measurement data. For example, if a current flowing through a built-in motor of the monitoring target is measured and the monitoring target determines that the motor is abnormal on the basis of a measured value of the current, the monitoring target may add a value to the measurement data, indicating any abnormality of the motor or the monitoring target.

[0018] The index contained in the index data is expressed as a combination of at least an index value and time corresponding to the index value. The index value is calculated from one or more measured values of one or more measurement items. For example, the index value may be calculated from measured values of plural currents during a predetermined term. For example, a single index value may be calculated using five values of current. Alternatively, the index value may be calculated on the basis of one measured value of current and one measured value of engine temperature in a same time period. Incidentally, if the absolute value of a difference between measurement times is equal to or smaller than a predetermined value, the measurement times may be considered to belong to a same time period.

[0019] The time corresponding to the index value may be the same as the measurement time corresponding to the measured value used to calculate the index value. If the index value is calculated from plural measured values differing in measurement time, the time corresponding to the index value can be calculated on the basis of a statistic of plural measurement times. For example, a mean value, a median, or the like of plural measurement times may be used as the time corresponding to the index value.

[0020] FIG. 2 is a diagram describing index data. The plots indicated by circles represent indices. The ordinate represents index value and the abscissa represents time corresponding to the index value. The dotted lines in FIG. 2 represent an upper limit and a lower limit of index values, respectively, expected to be measured when the monitoring target is normal. That is, when the index values fall within a range between the upper limit and the lower limit, the monitoring target is considered to be normal. An index value range in which the monitoring target is considered to be normal is referred to as an allowable range. In FIG. 2, the indices within the allowable range are indicated by white circles and the indices outside the allowable range are indicated by black circles. The indices outside the allowable range are referred to as

deviation cases.

[0021] The deviation cases indicate that the monitoring target is deviated from a normal state. That is, it is highly likely that the monitoring target is abnormal. However, it is not that all deviation cases indicate abnormality of the monitoring target.

[0022] As described above, measurement data includes measured values taken when the monitoring target is operating. When the monitoring target is operating, it is more likely that measurement data contains disturbances than when the monitoring target is stopped, and accuracy of the index tends to fall. For example, if the monitoring target is a vehicle and a current flowing through a specific region is being measured, when the vehicle is being driven, it is highly likely that measurement data contains disturbances and that measured values contain abnormal values.

[0023] Hence, when any disturbance gets into measurement data, a calculated index may exhibit abnormal values, resulting in deviation cases. Since deviations can be caused by disturbances in this way, it is necessary to determine whether a given deviation case is due to a disturbance or due to abnormality of the monitoring target.

[0024] Therefore, the data processing apparatus removes any index related to a disturbance from the calculated index data and thereby refines the index data. Then, the use of refined index data makes it possible to grasp the state of the monitoring target with high accuracy.

[0025] An internal configuration of the data processor will be described. The measurement data acquirer 1 acquires measurement data. The measurement data acquirer 1 may acquire measurement data directly from a sensor or the like or indirectly via an external apparatus. The measurement data acquirer 1 may manipulate the measurement data to calculate the measurement data to be processed by the data processor 3. For example, after removing unnecessary measurement items, the measurement data acquirer 1 may calculate a single item of measurement data by combining plural items of measurement data.

[0026] The storage 2 stores data used for various processes of the data processor 3. The data is stored beforehand in the storage 2. Also, data inputted in the data processor 3, data calculated in various processes of the data processor 3, and other data may be stored, and there is no specific limit to the data to be stored. Incidentally, the storage 2 may be divided according to stored data.

[0027] The data processor 3 processes measurement data and calculate index data. Details will be described together with the internal configuration.

[0028] The output device 4 outputs data related to the data processor 3. For example, the output device 4 outputs an exclusion condition described later, refined index data, and a determination result based on the refined index data. Also, the output device 4 may output data used in processes of various components as well as processing results

produced by the various components.

[0029] Incidentally, the data outputted by the output device 4 is not specifically limited, and data stored in the storage 2 may be outputted. Also, the output scheme of the output device 4 is not specifically limited. Images, voice, and the like may be outputted to a display or the like and an electronic file containing processing results may be saved in an external storage.

[0030] The internal configuration of the data processor 3 will be described. The index calculator 31 calculates index data on the basis of measurement data. The index calculator 31 may calculate an index value on the basis of one or more measured values using a predetermined calculation formula. Alternatively, the measured value itself may be used as an index value. Regarding the calculation formula, a well-known calculation formula may be used.

[0031] The exclusion condition calculator 32 calculates a condition for removing index data related to disturbances from index data. The condition is referred to as an exclusion condition. On the basis of the exclusion condition, the indices in the index data are divided into indices marked for exclusion and indices marked to be checked for deviation.

[0032] The exclusion condition is used to determine whether first measurement data or second measurement data is measured in a circumstance under which disturbances are prone to get in. The first measurement data is used to calculate a given index. The second measurement data is measured in a same time period as the first measurement data. As a circumstance under which disturbances are prone to get in, a predetermined operating state can be defined in advance according to the monitoring target.

[0033] For example, when index values are calculated on the basis of measured values of current, if an exclusion condition for velocity measured in a same time period as the measured values of current is used, it is possible to remove indices of the monitoring target during high-speed travel during which disturbances are prone to get in. Measurement items used to calculate indices and measurement items used to calculate the exclusion condition may be established in advance.

[0034] The predetermined operating state may simply be a state in which the monitoring target is operating or an operating state in which an output value and the like are equal to or higher than predetermined values. For example, when the monitoring target is an electric generator or the like, the predetermined operating state may be a state in which electric power equal to or higher than a predetermined value is generated. Alternatively, the predetermined operating state may be a state in which power consumption of the monitoring target is equal to or higher than a predetermined value. Alternatively, when the monitoring target is a vehicle, the predetermined operating state may be a state in which the vehicle is running at a speed equal to or

higher than a predetermined value. Alternatively, when internal temperature of the monitoring target is equal to or higher than a predetermined value, it may be considered that the monitoring target is operating at high loads. In this way, it becomes clear whether the first measurement data or the second measurement data has been measured in a predetermined operating state and it becomes possible to determine that the index calculated from the first measurement data is highly likely to have been affected by a disturbance.

[0035] FIG. 3 is a diagram illustrating an example of an exclusion condition. The exclusion condition in FIG. 3 use a decision tree. Suppose, for example, measurement data contains measured values on three sensors A, B, and C. The index is created on the basis of at least any of the three sensors A, B, and C, and the exclusion condition is also created on the basis of at least any of the three sensors A, B, and C.

[0036] With the exclusion condition in FIG. 3, first, the index value is classified on the basis of the measured value on the sensor A. If the measured value on the sensor A is 3 or above, the index is determined to be a deviation. If the measured value on the sensor A is less than 3, the index value is further classified on the basis of the measured value on the sensor B. If the measured value on the sensor B is less than 5.2, the index is determined to be a deviation, and if the measured value on the sensor B is 5.2 or above, the index value is determined to be excluded.

[0037] Under the exclusion condition described above, for example, when indices are calculated using all the measured values on the sensors A, B, and C, the indices calculated when the measured value on the sensor A is 2 and the measured value on the sensor B is 6 are marked for exclusion. Also, in the case where indices are calculated on the basis of only the measured values on the sensor C, when the measured value on the sensor A is 2 and the measured value on the sensor B is 6 at 13 o'clock, the index calculated from the measured value on the sensor C at 13 o'clock is also marked for exclusion.

[0038] Incidentally, the measurement items of each of the sensors may be either identical or different. For example, both the sensor A and the sensor B may measure current at a same site. Alternatively, the sensor B may measure current at a site different from the sensor A. Alternatively, the sensor A may measure current and the sensor B may measure voltage.

[0039] The exclusion condition can be calculated using machine learning based on determination results produced by the deviation determiner 34. Regarding the machine learning, a well-known technique may be used. Machine learning techniques include, for example, a method which uses a model for classifying indices into a group containing indices marked to be checked for deviation and a group containing indices marked for exclusion.

- [0040] Also, there is a technique for calculating an exclusion condition by quantifying degrees of deviation of indices and carrying out sparse regression. It is conceivable to calculate degrees of deviation on the basis of differences from a reference value or the nearest limit value. An exclusion condition may be calculated on the basis of a statistic of the indices such as a mean value and a median.
- [0041] The excluder 33 (refiner) removes index data related to disturbances from index data on the basis of an exclusion condition and thereby refines the index data.
- [0042] The deviation determiner 34 determines whether each index in the refined index data deviates from a predetermined allowable range. Incidentally, of the predetermined allowable range, only either of an upper limit and a lower limit may be prescribed. That is, when an index is equal to or smaller than the upper limit or equal to or larger than the lower limit, the index may be determined to be allowable. Also, the allowable range may be set to be within a predetermined value above and below the reference value. For example, if the reference value of current is 10 A, the allowable range may be set to be 0.5 A above and below the reference value. In this case, measured values of current falling within a range of 9.5 A to 10.5 A are determined to be allowable.
- [0043] The allowable range may be changed according to the state of the monitoring target. For example, it is conceivable that the allowable range of indices related to measurement data varies between when the monitoring target is moving and when the monitoring target is stopped. The state of the monitoring target can be determined on the basis of the measurement data.
- [0044] FIG. 4 is a diagram illustrating processing results produced by the excluder 33 and the deviation determiner 34. FIG. 4 is also an example of output from the output device 4. Triangular plots and square plots indicate indices excluded by the excluder 33 among the indices illustrated in FIG. 2. In FIG. 4, it is assumed that the excluder 33 has performed refinement using plural conditions making up an exclusion condition such as illustrated in FIG. 3. The conditions making up an exclusion condition is referred to as sub conditions. The indices indicated by triangles are indices excluded under a first sub condition and the indices indicated by squares are indices excluded under a second sub condition. As illustrated in FIG. 4, even indices within the allowable range may be marked for exclusion.
- [0045] In FIG. 4, the indices marked to be checked for deviation are indicated by circles. Of the indices indicated by circles, the indices outside the allowable range are indicated by black circles. In this way, the deviation determiner 34 determines whether each index marked to be checked for deviation is deviated from the allowable range.
- [0046] Incidentally, as illustrated in FIG. 4, by changing the shape, color, and the like of

plots, the output device 4 may display whether each index is within an allowable range, is outside the allowable range, or has been excluded. Also, a deviation rate may be outputted. The deviation rate is calculated by a division using the number of indices marked to be checked for deviation as a numerator and using the number of deviated indices as a denominator.

[0047] Also, the output device 4 may output the degrees of deviation of indices marked to be checked for deviation, during a predetermined term such as one day or one week. FIG. 5 is a diagram illustrating an example of an output produced by the output device 4. FIG. 5 is a box-and-whisker diagram illustrating distributions of index data on a day-to-day basis. The output device 4 may change a display form in this way.

[0048] Next, a flow of processes performed by components of the data processing apparatus will be described. FIG. 6 is a diagram illustrating an example of a schematic flowchart of an overall process performed by the data processing apparatus according to the first embodiment.

[0049] The measurement data acquirer 1 acquires measurement data (S101). The index calculator 31 calculates index data on the basis of the measurement data (S102). Incidentally, an index value may be calculated each time when a measured value is acquired. Alternatively, an index value may be calculated all at once when a predetermined number of measured values are acquired.

[0050] The exclusion condition calculator 32 calculates an exclusion condition on the basis of a history of past deviation determinations and measurement data related to the past deviation determinations (S103). Incidentally, when there is no history of past deviation determinations, a predetermined condition (initial condition) is used as an exclusion condition.

[0051] On the basis of the exclusion condition calculated by the exclusion condition calculator 32, the excluder 33 excludes any index marked for exclusion from the index data received from the index calculator 31 (S104). Each index in the index data refined as the exclusion condition calculator 32 has excluded the indices marked for exclusion is checked for deviation by the deviation determiner 34 (S105). The deviation determiner 34 updates the deviation determination history (S106). Consequently, the exclusion condition is updated in a next process. Then, the output device 4 displays processing results and the like (S107), thereby finishing the present flow.

[0052] Incidentally, the flowchart is only an example, and the processing order and the like are not limited as long as necessary processing results are available. For example, the process of S103 may be carried out before the processes of S101 and S102. Also, results of each process may be sequentially stored in the storage 2, and each component may acquire processing results by referring to the storage 2.

[0053] As described above, the present embodiment can remove unnecessary disturbances from measurement data. Therefore, the present embodiment makes it possible to grasp the present state of the monitoring target with high accuracy from measurement data acquired during operation of the monitoring target and even containing lots of disturbances. As a result, the present embodiment makes it possible to reduce the inspection frequency of the monitoring target, omit unnecessary inspections, and curb maintenance costs.

[0054] Incidentally, the data processing apparatus may be made up of plural apparatus capable of exchanging data via communications or electrical signals. For example, the data processing apparatus may be divided into a first apparatus provided with the excluder 33 and the like and configured to create refined index data and a second apparatus provided with the deviation determiner 34 and configured to determine deviations.

(Second Embodiment)

[0055] FIG. 7 is a block diagram illustrating an example of a schematic configuration of a data processing apparatus according to a second embodiment. The second embodiment differs from the first embodiment in further having an input device 5 configured to receive input from a user. Description of points similar to the first embodiment will be omitted.

[0056] Once the output device 4 outputs the exclusion condition calculated by the exclusion condition calculator 32, users such as a monitoring staff and an administrator of the monitoring target can determine whether or not the outputted exclusion condition is appropriate. There can be cases in which it is desired to ease or strengthen the exclusion condition.

[0057] Hence, according to the present embodiment, the input device 5 receives input related to an exclusion condition. For example, parameters needed to create an exclusion condition, modifications to a calculated exclusion condition, and the like are inputted. On the basis of input values received by the input device 5, an exclusion condition creator creates or modifies an exclusion condition.

[0058] FIG. 8 is a diagram describing modification of an exclusion condition. A GUI (Graphical User Interface) illustrated in FIG. 8 is outputted by the output device 4 to receive modifications from the user.

[0059] On the right side of FIG. 8, an exclusion condition calculated using a decision tree is displayed in a tree structure. Calculation conditions for the exclusion condition are displayed on the left side of FIG. 8. A term of learning data used for the calculation, an applied technique, and applied conditions are displayed as the calculation conditions. The applied technique is a machine learning technique which has been applied. Settings of the applied conditions vary with the selected applied technique. In

the case of a decision tree, because a machine learning technique is applied as a classification problem, it is necessary to select groups for use in the classification. In the example of FIG. 8, indices are classified into a group of indices within an allowable range and a group of indices outside the allowable range. The indices may be classified into two groups according to the distance from the reference value.

[0060] The GUI in FIG. 8 lends itself to changes in display contents and functions as an input interface for use to modify an exclusion condition. That is, when changes in the GUI is inputted to the input device 5, the exclusion condition calculator 32 recreates the exclusion condition on the basis of the changes.

[0061] For example, it is conceivable to adjust a threshold for an exclusion condition. In the example of FIG. 8, after changing a threshold in the tree structure illustrated on the right side, when the user presses the "Modify Model" button displayed at the bottom of the screen, the exclusion condition with the threshold modified is re-created.

[0062] Incidentally, it is preferable that the settings of decision tree parameters can also be changed. Conceivable parameters include a tree-building algorithm and pruning range.

[0063] In the case where a model with a desired accuracy is not created even if exclusion condition parameters are adjusted, or in similar cases, it is conceivable to change or rebuild the model. After determining necessary items for exclusion condition calculation on the left side of FIG. 8, when the user presses the "Rebuild Model" button displayed at the bottom of the screen, a new exclusion condition is created (the exclusion condition is recreated).

[0064] Incidentally, if there is no problem with the exclusion condition, the user may press the "Apply Model" button displayed at the bottom of the screen. The output device 4 may be set to output the GUI in FIG. 8 after the exclusion condition calculator 32 calculates an exclusion condition, and the processes of the excluder 33 and the deviation determiner 34 may be set to be performed only when the "Apply Model" button is pressed. In this way, processing may be set to proceed only upon confirmation by the user to prevent output of unsatisfactory processing results.

[0065] Next, a flow of exclusion condition update will be described. FIG. 9 is a diagram illustrating an example of a flowchart of an exclusion condition update process. It is assumed that the present flow is carried out between S103 and S104 of the overall process illustrated in FIG. 6. Also, the present flow may be carried out after the process of S107 and the process of S104 may be carried out again after the end of the present flow.

[0066] The output device 4 outputs an exclusion condition using a GUI such as illustrated in FIG. 8 (S201). If the outputted exclusion condition is not approved (NO in S202), the exclusion condition modified on the GUI is acquired by the input device 5

(S203). The modified exclusion condition is passed to the exclusion condition calculator 32, which then updates the exclusion condition (S204). The updated exclusion condition is outputted again by the output device 4 (S201). In this way, the processes of S201 to S204 are repeated until the exclusion condition is approved. Then, when the exclusion condition is approved (YES in S202), the present flow is finished.

[0067] As described above, according to the present embodiment, the exclusion condition calculator 32 creates or modifies an exclusion condition on the basis of the input to the input device 5. This makes it possible to create an exclusion condition in which ideas and experiences of the user are reflected and ensure validity of disturbance removal method.

(Third Embodiment)

[0068] FIG. 10 is a block diagram illustrating an example of a schematic configuration of a data processing apparatus according to a third embodiment. The third embodiment differs from the embodiments described above in that the data processor 3 further includes a counter 35. Whereas in FIG. 10, the counter 35 is added to the second embodiment, the counter 35 may be added to another embodiment. Description of points similar to the embodiments described above will be omitted.

[0069] The counter 35 counts the number of indices contained in the refined index data. The number of the indices contained in the refined index data will be referred to as a sample count. That is, it can be said that the counter 35 counts the number of effective samples in the index data. If the sample count in the index data is equal to or larger than a predetermined threshold, it is considered that the index data is reliable. For example, in the case of processing results illustrated in FIG. 4, the sample count is 11, which is equal to the number of indices marked to be checked for deviation.

[0070] It is assumed that the threshold for samples has been established in advance. Also, sample counts may be counted at predetermined terms by being classified according to the state of the monitoring target.

[0071] FIG. 11 is a diagram illustrating an example of results on counted sample counts. It is conceivable that the output device 4 outputs a table such as in FIG. 11. In FIG. 11, sample counts are counted by being classified into three operation modes and five terms. The operation modes represent types of state of the monitoring target. The terms may be set as desired. Lengths of the terms do not need to be fixed.

[0072] For example, when the monitoring target is a vehicle, in one conceivable situation, the vehicle has three operation modes: accelerating, decelerating, and stopped temporarily. Then, if the term from 0 o'clock to 5 o'clock is divided into one-hour intervals and sample counts are counted by being classified according to the

operation mode and term, count results such as in FIG. 11 are produced.

[0073] The numbers in parentheses in FIG. 11 indicate thresholds of sample counts. The thresholds may vary with the term and the operation mode. In the example of FIG. 11, it is assumed that terms 4 and 5 are longer than terms 1 to 3. Consequently, the threshold values for terms 4 and 5 are set larger than the threshold values for terms 1 to 3. In this way, the thresholds of sample counts may also be outputted.

[0074] In the example of FIG. 11, the sample count in operation mode 3 in term 4 is smaller than its threshold. Thus, it is conceivable that the index data in operation mode 3 in term 4 has low reliability.

[0075] FIG. 12 is a diagram illustrating another example of results on counted sample counts. Whereas count results are shown in tabular form in FIG. 11, the count results may be shown in a bar chart as illustrated in FIG. 12. A display format of sample count results may be allowed to specify via the input device 5 shown in the second embodiment.

[0076] A count process performed by the counter 35 can be performed after the excluder 33 excludes the indices marked for exclusion, on the basis of the exclusion condition. In other words, in the flow illustrated in FIG. 6, the count process can be performed after the process of S104. A flowchart according to the present embodiment is omitted.

[0077] As described above, according to the present embodiment, the number of effective samples in the index data is counted. This allows the sample count in refined index data to be verified, guaranteeing reliability of the outputted index data.

(Fourth Embodiment)

FIG. 13 is a block diagram illustrating an example of a schematic configuration of a data processing apparatus according to a fourth embodiment. The fourth embodiment differs from the embodiments described above in that the data processor 3 further includes a state determination condition calculator 36 and a state determiner 37. Whereas in FIG. 13, these components are added to the third embodiment, the components may be added to another embodiment. Description of points similar to the embodiments described above will be omitted.

[0078] According to the present embodiment, the data processing apparatus itself performs state determinations and determines the state of the monitoring target. State determination results on the monitoring target can be used in various applications. For example, a next inspection may be omitted in the case of sites determined to be normal on the basis of the determination. Also, if the monitoring target is determined to be abnormal in the determination, the output device 4 may output an alert in the form of an image or sound. In this case, it can be said that the data processing apparatus is both a state determination apparatus and an abnormality detection apparatus.

- [0079] Since measurement data is acquired during operation of the monitoring target, if the state of the monitoring target is determined immediately by acquiring measurement data in real time each time a measurement is taken, abnormalities can be detected in real time.
- [0080] The state determination condition calculator 36 calculates state determination conditions, which are used in state determination. The state determination conditions are calculated using a learning model for use in calculating the state determination conditions. The model will be referred to as a learning model for state determination condition calculation. The learning model for state determination condition calculation is updated by learning evaluations (correct answers) of state determination as the evaluations are inputted by the user or the like. This improves the accuracy of the state determination conditions. Regarding a learning method, a well-known technique may be used in the same way as when the exclusion condition calculator 32 calculates an exclusion condition. The above-mentioned evaluations of state determination are acquired via the input device 5.
- [0081] FIG. 14 is a diagram describing evaluation input with respect to state determination. The GUI illustrated in FIG. 14 is an interface used to receive evaluations of state determinations outputted from the output device 4. Deviation rates and sample counts classified according to the term and the operation mode are shown. In the example of FIG. 14, two buttons are available: "Inspection Laborsaving Available" and "Inspection Laborsaving Unavailable." The buttons are used to specify whether inspection of the items whose checkboxes are marked can be omitted.
- [0082] Grayed fields indicate that the deviation rate or the sample count has not been recognized as normal. In the example of FIG. 14, the deviation rate in operation mode 1 in term 1 is high and the sample count in operation mode 3 in term 4 is low. Consequently, it is likely to be determined that these two inspections cannot be omitted.
- [0083] FIG. 15 is a diagram illustrating an example of a history of correct answers to state determination. Incidentally, items other than those shown in FIG. 15 may be included in the correct answers. It is assumed that such a correct answer history is accumulated in the storage 2. Then, by using the correct answer history as learning data, machine learning is performed as a classification problem of classifying refined index data, and consequently state determination conditions are calculated. A well-known technique can be used for the machine learning. Incidentally, state determination conditions may be calculated for each operation mode by conducting learning in relation to each operation mode.
- [0084] Thus, the state determination condition calculator 36 repeats learning on the basis of the state of the monitoring target determined by the state determiner and data

concerning validity of the state, and thereby updates the learning model for state determination condition calculation. As the state determination conditions are calculated from the updated learning model for state determination condition calculation, the accuracy of the state determination conditions is improved. Incidentally, if state determination conditions are provided by the user via the input device 5, the state determination condition calculator 36 may be omitted.

[0085] On the basis of the state determination conditions, the state determiner 37 determines the state of the monitoring target from the determination results produced by the deviation determiner 34. Incidentally, the state of the monitoring target may be classified into two types: normal and abnormal. Alternatively, the state of the monitoring target may be classified into three or more types according to the extent of divergence from the reference value.

[0086] On the basis of the determined state of the monitoring target, the state determiner 37 may determine whether or not the monitoring target needs to be inspected. For example, when the state is determined to be normal, the state determiner 37 may determine that predetermined inspection items may be omitted. Also, for example, when the deviation rate is equal to or higher than 5% but lower than 10%, the state determiner 37 may determine that the state of the monitoring target needs to be closely watched and that inspection in relation to a first inspection item may be omitted but not a second inspection item.

[0087] If the sample count counted by the counter 35 is smaller than a threshold, the state determiner 37 may not perform state determination or may add a warning that the determination results have low reliability. For example, as with the example of FIG. 14, when the sample count does not satisfy conditions, the state determiner 37 may determine that inspection cannot be omitted because the state cannot be determined accurately. Incidentally, a state determination may be made in relation to each operation mode. If there are inspection items corresponding to each operation mode, in the example of FIG. 11, inspection items related to operation mode 1 and operation mode 2 may be omitted while inhibiting omission of inspection items related to operation mode 3.

[0088] State determination results produced by the state determiner 37 are outputted from the output device 4. Outputted information is assumed to include the state of the monitoring target, whether or not inspection can be omitted and reasons therefor, and inspection items which can be omitted. For example, the output device 4 may display a message on a monitor connected to the data processing apparatus, indicating that the inspection cannot be omitted because the deviation rate is higher than the threshold and the sample count in operation mode 3 in term 4 is insufficient.

[0089] Next, a flow of state determination will be described. FIG. 16 is a diagram il-

lustrating an example of a flowchart of state determination. It is assumed that the present flow is carried out after S105 of the overall process illustrated in FIG. 6.

[0090] On the basis of the state determination conditions, the state determiner 37 determines the state from index data (S301). The determination results may be either outputted together with the processing results of the above embodiments or outputted separately. Then, the output device 4 outputs a GUI for correct answer input (S302). As the user operates the GUI for correct answer input, the input device 5 receives a correct answer to state determination (S303). Then, the state determination condition calculator 36 updates the state determination conditions on the basis of the index data and correct answer history (S304), thereby finishing the present flow. Consequently, the updated state determination conditions are used in a next process, improving the accuracy of the state determination.

[0091] As described above, the data processing apparatus according to the present embodiment also determines the state of the monitoring target on the basis of index data. This makes it possible to automate determinations on the state of the monitoring target, on omission of inspection, and so on. Besides, state determination conditions can also be created automatically through learning.

[0092] Each process in the embodiments described above can be implemented by software (program). Thus, the embodiments described above can be implemented using, for example, a general-purpose computer apparatus as basic hardware and causing a processor mounted in the computer apparatus to execute the program.

[0093] FIG. 17 is a block diagram illustrating an example of hardware configuration according to one embodiment of the present invention. The data processing apparatus includes a processor 61, a main storage 62, an auxiliary storage 63, a network interface 64, and a device interface 65, which are interconnected via a bus 66 and implemented as a computer apparatus 6. Also, the data processing apparatus may further include an input apparatus and an output apparatus.

[0094] The data processing apparatus according to the present embodiment may be implemented by pre-installing a program executed by each apparatus on the computer apparatus 6 or by installing the program in a storage medium such as a CD-ROM or distributed through a network on the computer apparatus 6 as required.

[0095] Incidentally, in FIG. 17, the computer apparatus includes one each of all components, but may include plural units of each component. Also, whereas a single computer apparatus is illustrated in FIG. 17, software may be installed on plural computer apparatus. Each of the plural computer apparatus may execute the process of different part of the software to produce processing results. That is, the data processing apparatus may be configured as a system.

[0096] The processor 61 is an electronic circuit including a control device and arithmetic

device of the computer. The processor 61 performs arithmetic processing on the basis of data or programs inputted from various devices inside the computer apparatus 6 and outputs computational results and control signals to various apparatus. Specifically, the processor 61 performs an OS (operating system) of the computer apparatus 6 or applications and controls various devices of the computer apparatus 6.

[0097] The processor 61 is not specifically limited as long as the above processes can be performed. The processor 61 may be, for example, a general-purpose processor, a central processing unit (CPU), a microprocessor, a digital signal processor (DSP), a controller, a microcontroller, or a state machine. Also, the processor 61 may be incorporated into an application specific integrated circuit, a field programmable gate array (FPGA), or a programmable logic device (PLD). Also, the processor 61 may be made up of plural processing devices. For example, the processor 61 may be a combination of a DSP and a microprocessor or one or more microprocessors configured to collaborate with a DSP core.

[0098] The main storage 62 is a storage device configured to store commands executed by the processor 61 as well as various data, and information stored in the main storage 62 is read directly by the processor 61. The auxiliary storage 63 is a storage device other than the main storage 62. Incidentally, the term "storage device" means any electronic part capable of storing electronic information. Volatile memories, such as a RAM, a DRAM, and an SRAM, for use to temporarily save information are mainly used as the main storage 62, but in embodiments of the present invention, the main storage 62 is not limited to these volatile memories. The storage devices used as the main storage 62 and the auxiliary storage 63 may be either volatile or nonvolatile memories. Nonvolatile memories include a programmable read-only memory (PROM), an erasable programmable read-only memory (EPROM), an electrically erasable PROM (EEPROM), a nonvolatile random access memory (NVRAM), a flash memory, and an MRAM. Also, a magnetic or optical data storage may be used as the auxiliary storage 63. Available data storages include a magnetic disk such as a hard disk, an optical disc such as a DVD, a flash memory such as a USB memory, and a magnetic tape.

[0099] Incidentally, if the processor 61 reads and/or writes information directly or indirectly from or to the main storage 62 or the auxiliary storage 63, it can be said that the storage devices electrically communicate with the processor. Incidentally, the main storage 62 may be integrated into the processor. Again, it can be said that the main storage 62 electrically communicates with the processor.

[0100] The network interface 64 is an interface for use to connect to a communication network by radio or wire. Any network interface 64 compatible with existing communication standards may be used. Through the network interface 64, output results and

the like may be transmitted to an external apparatus 8 connected on-line via a communication network 7.

- [0101] The device interface 65 is a USB or other interface for use to connect to the external apparatus 8 configured to record output results and the like. The external apparatus 8 may be an external storage medium or a storage such as a database. The external storage medium may be any recording medium such as an HDD, a CD-R, a CD-RW, a DVD-RAM, a DVD-R, or a SAN (Storage Area Network). Alternatively, the external apparatus 8 may be an output apparatus. For example, the external apparatus 8 may be a display apparatus configured to display images or an apparatus or the like configured to output voice or the like. Examples of the external apparatus 8 include an LCD (Liquid Crystal Display), a CRT (Cathode Ray Tube), a PDP (Plasma Display Panel), and a speaker, but the external apparatus 8 is not limited to these.
- [0102] Also, all or part of the computer apparatus 6, i.e., all or part of the data processing apparatus may be made up of a dedicated electronic circuit (i.e., hardware) such as a semiconductor integrated circuit equipped with the processor 61 and the like. The dedicated hardware may be constructed in combination with a storage device such as a RAM or a ROM.
- [0103] Incidentally, whereas a single computer apparatus is illustrated in FIG. 17, software may be installed on plural computer apparatus. Each of the plural computer apparatus may execute the process of different part of the software to produce processing results.
- [0104] While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

Claims

- [Claim 1] A data processing apparatus comprising:
- an index calculator configured to calculate index data containing an index which represent a state of a monitoring target on the basis of measurement data on the monitoring target;
- an exclusion condition calculator configured to calculate an exclusion condition for removing any index related to a disturbance from the index data on the basis of the measurement data; and
- a refiner configured to refine the index data by removing the index related to a disturbance from the index data on the basis of the exclusion condition and .
- [Claim 2] The data processing apparatus according to claim 1, wherein:
- the index represents a state of performance of the monitoring target; and
- the exclusion condition is for determining whether an index is related to the disturbance or not by determining whether second measurement data represents a predetermined operating state of the monitoring target, the second measurement data being measured in a same time period as first measurement data used to calculate the index.
- [Claim 3] The data processing apparatus according to claim 1 or 2, further comprising a deviation determiner configured to determine whether an index contained in the index data refined by the refiner are deviated from an allowable range.
- [Claim 4] The data processing apparatus according to claim 3, further comprising a state determiner configured to determine the state of the monitoring target from a determination result produced by the deviation determiner, on the basis of a state determination condition.
- [Claim 5] The data processing apparatus according to claim 4, wherein the state determiner determines whether or not the monitoring target needs to be inspected, on the basis of the determined state of the monitoring target.
- [Claim 6] The data processing apparatus according to claim 4 or 5, further comprising a state determination condition calculator configured to:
- update a learning model for calculating the state determination condition on the basis of the determined state of the monitoring target by the state determiner and data concerning validity of the determined state of the monitoring target, and

calculate the state determination condition on the basis of the learning model for calculating the state determination condition.

[Claim 7]

The data processing apparatus according to any one of claims 1 to 6, further comprising:

an output device configured to output at least the exclusion condition; and

an input device configured to receive input of data concerning the exclusion condition,

wherein the exclusion condition calculator recreates the exclusion condition on the basis of the data concerning the exclusion condition received by the input device.

[Claim 8]

The data processing apparatus according to any one of claims 1 to 7, further comprising a counter configured to count the number of indices contained in the index data refined by the refiner.

[Claim 9]

A data processing method comprising:

calculating index data containing indices which represent a state of a monitoring target on the basis of measurement data on the monitoring target;

calculating an exclusion condition for removing any index related to a disturbance from the index data on the basis of the measurement data; and

removing the index related to a disturbance from the index data on the basis of the exclusion condition and thereby refining the index data.

[Claim 10]

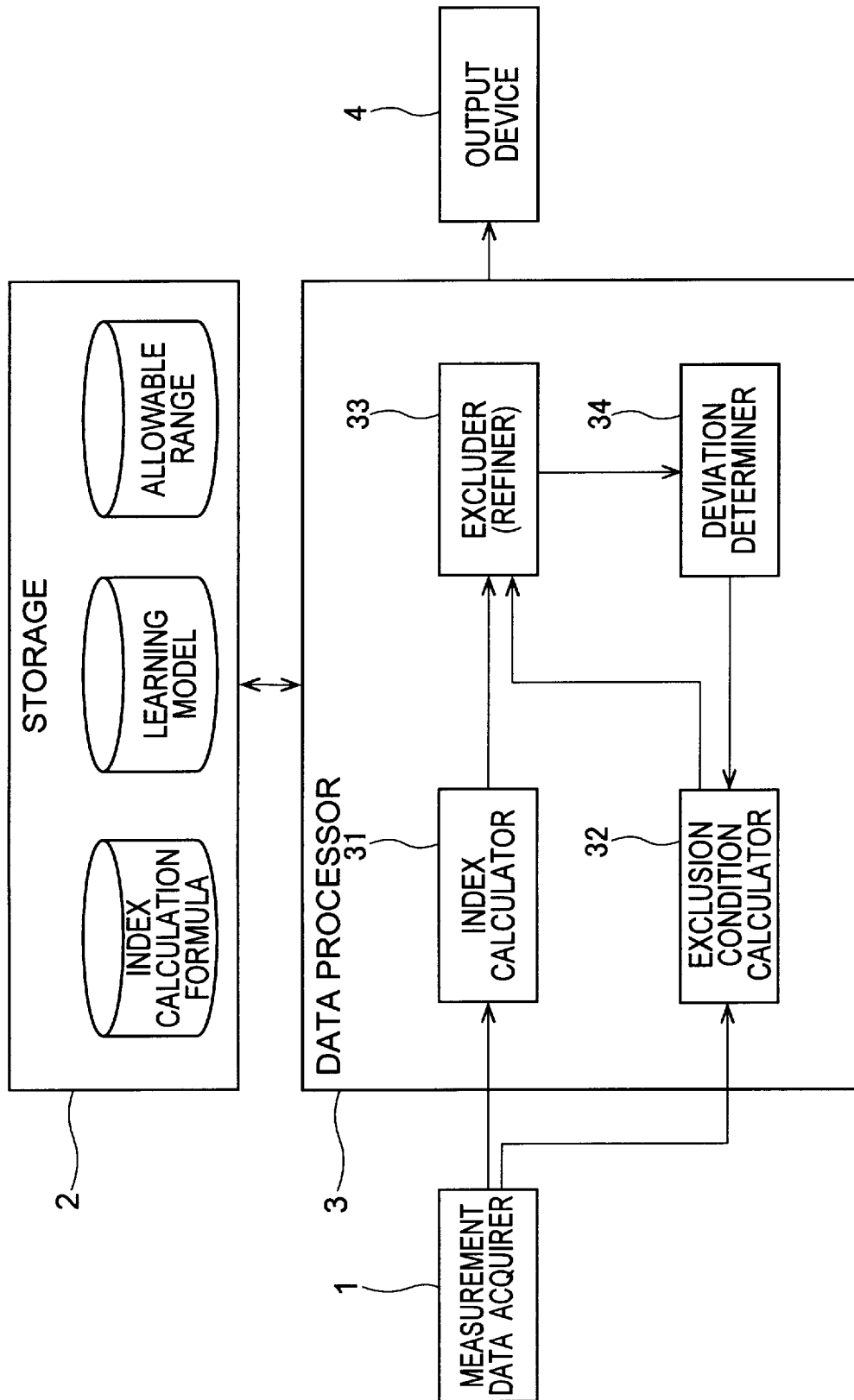
A program configured to cause a computer to:

calculate index data containing indices which represent a state of a monitoring target on the basis of measurement data on the monitoring target;

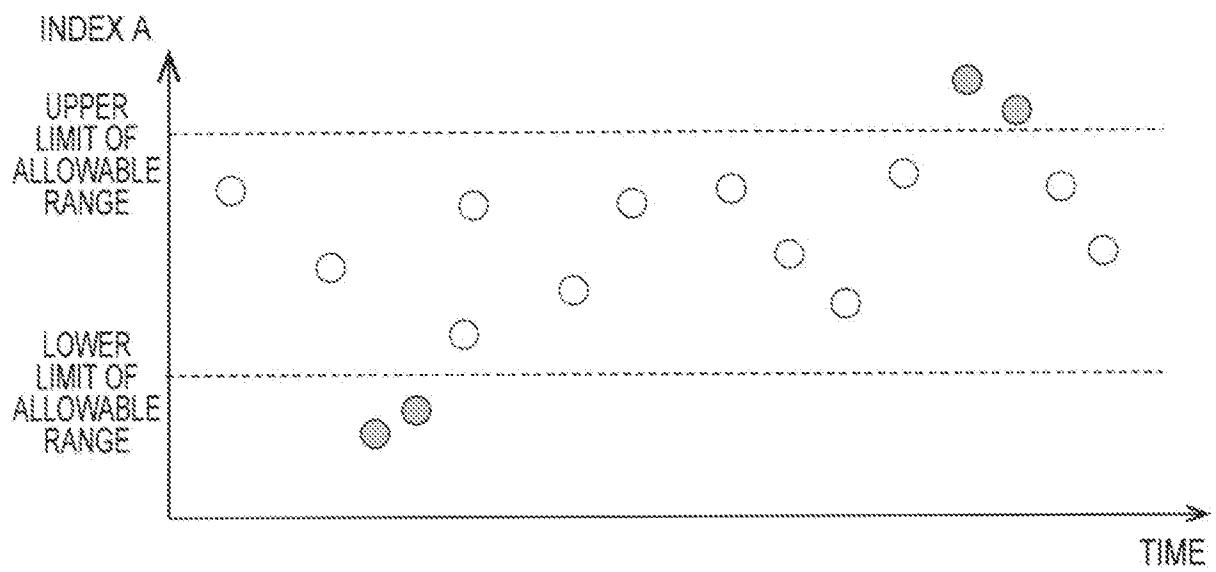
calculate an exclusion condition for removing any index related to a disturbance from the index data on the basis of the measurement data; and

remove the index related to a disturbance from the index data on the basis of the exclusion condition and thereby refine the index data.

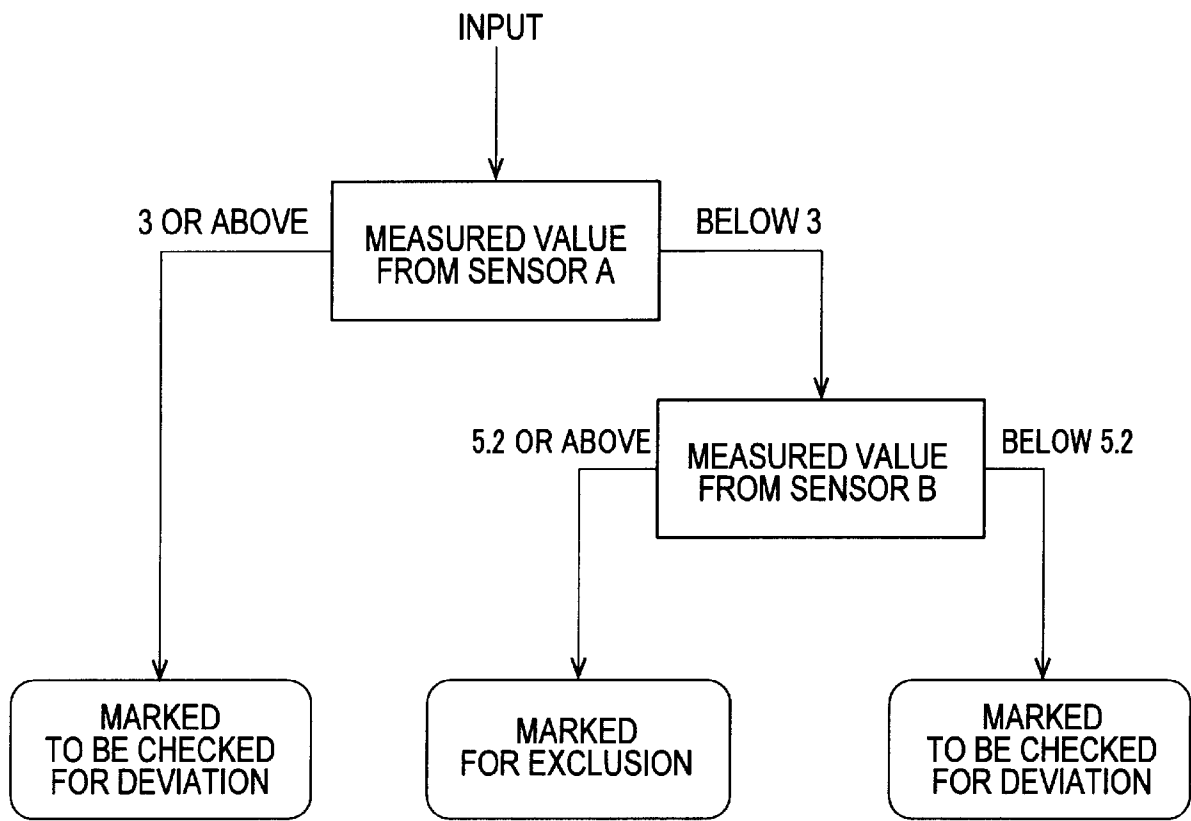
[Fig. 1]



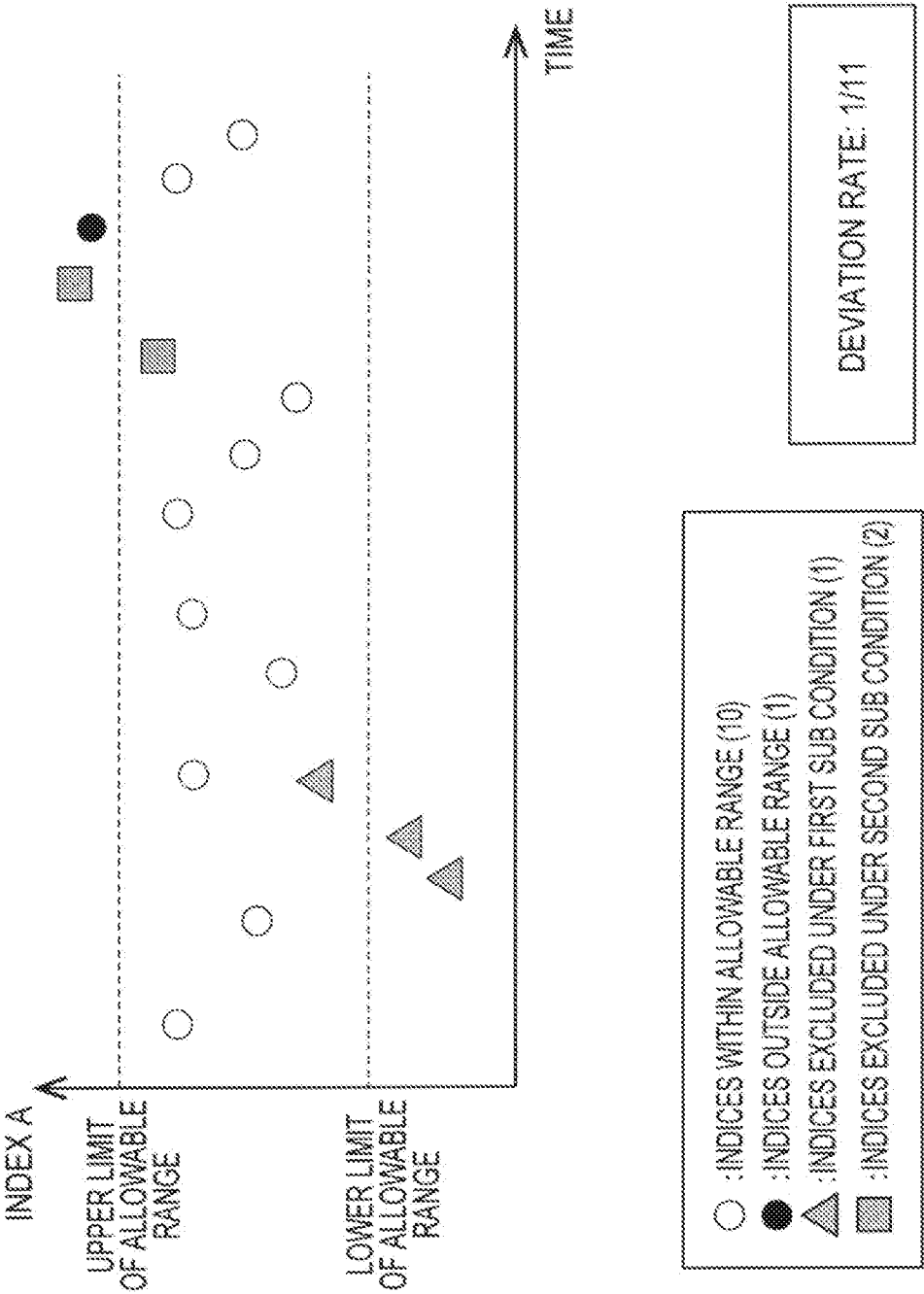
[Fig. 2]



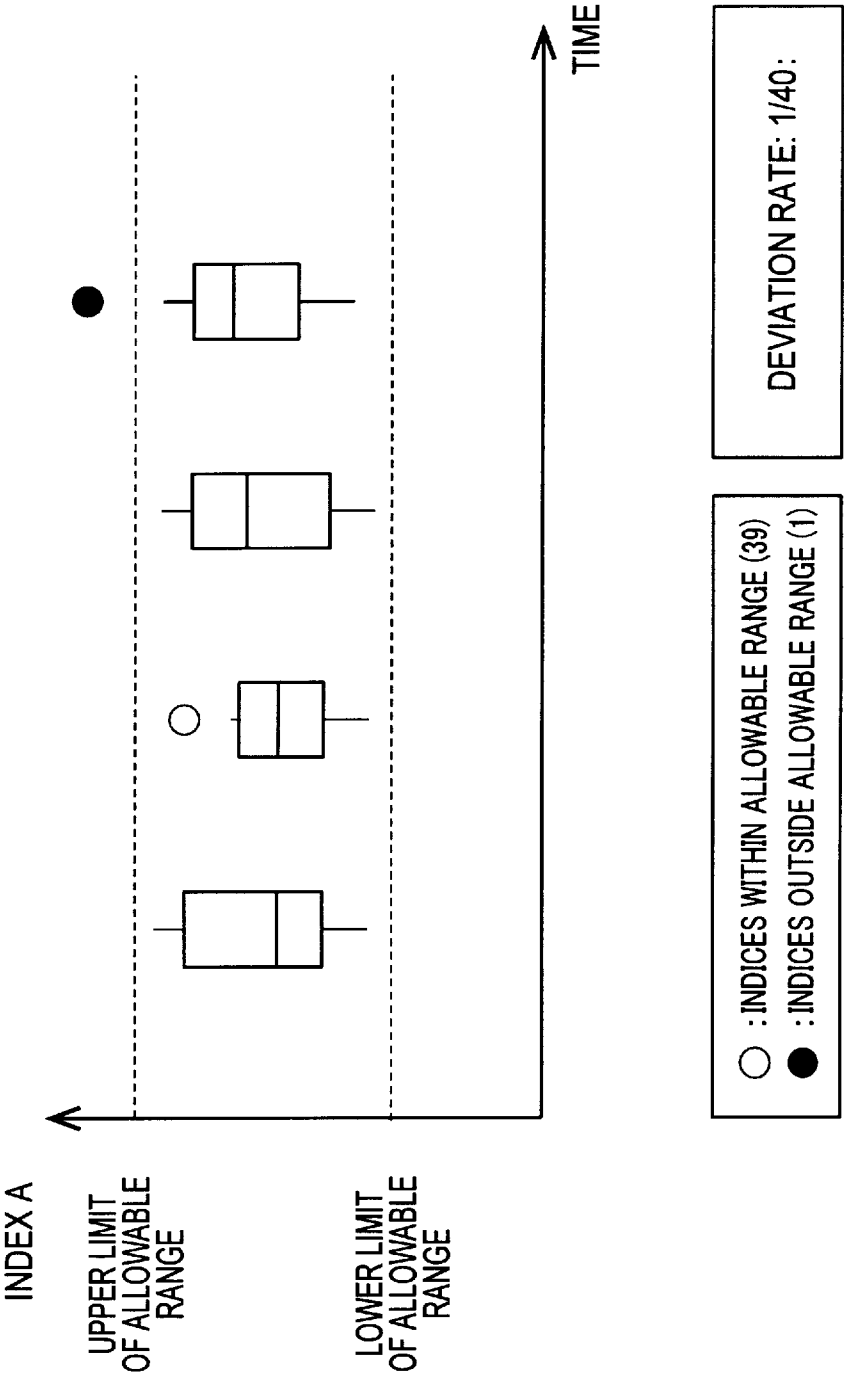
[Fig. 3]



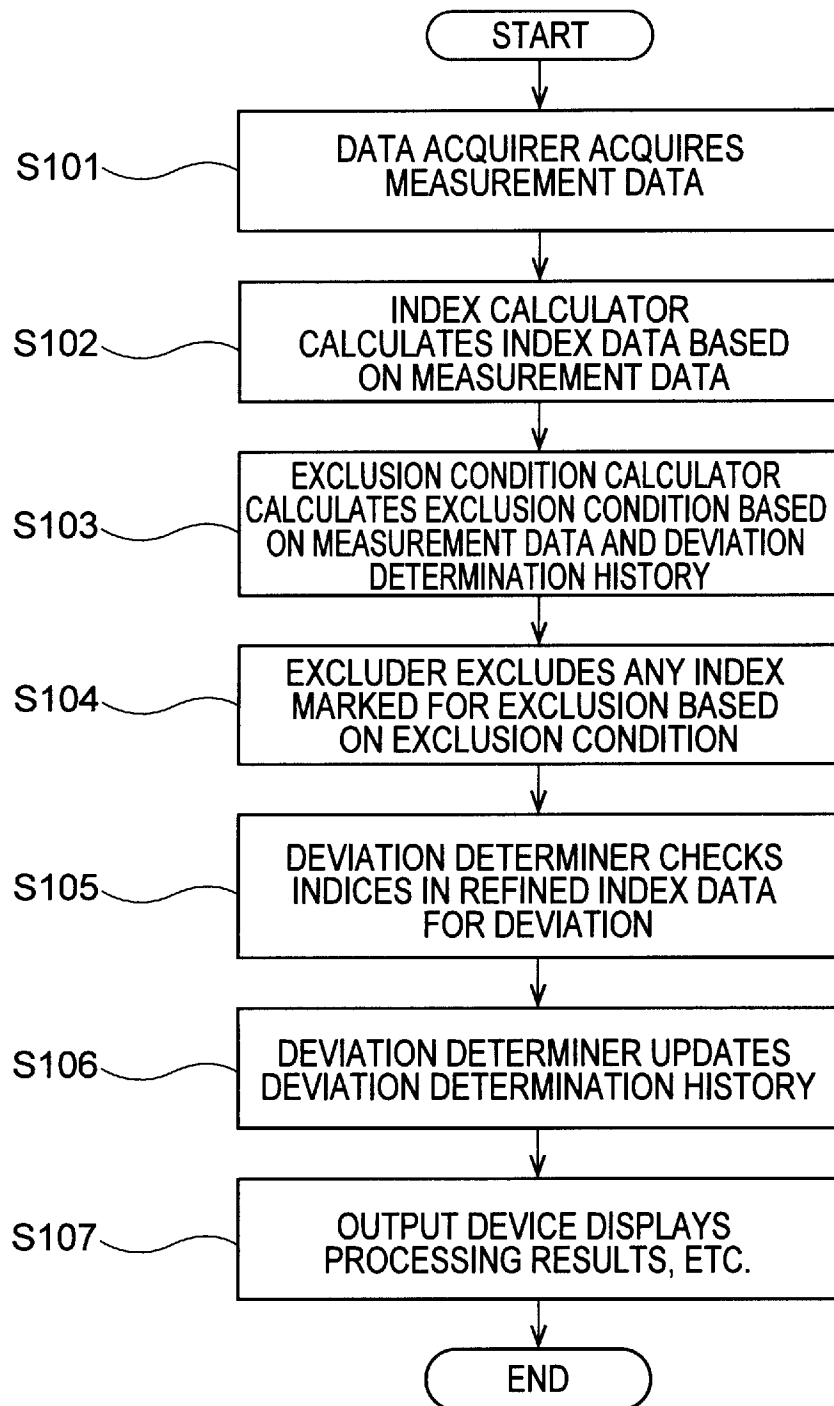
[Fig. 4]



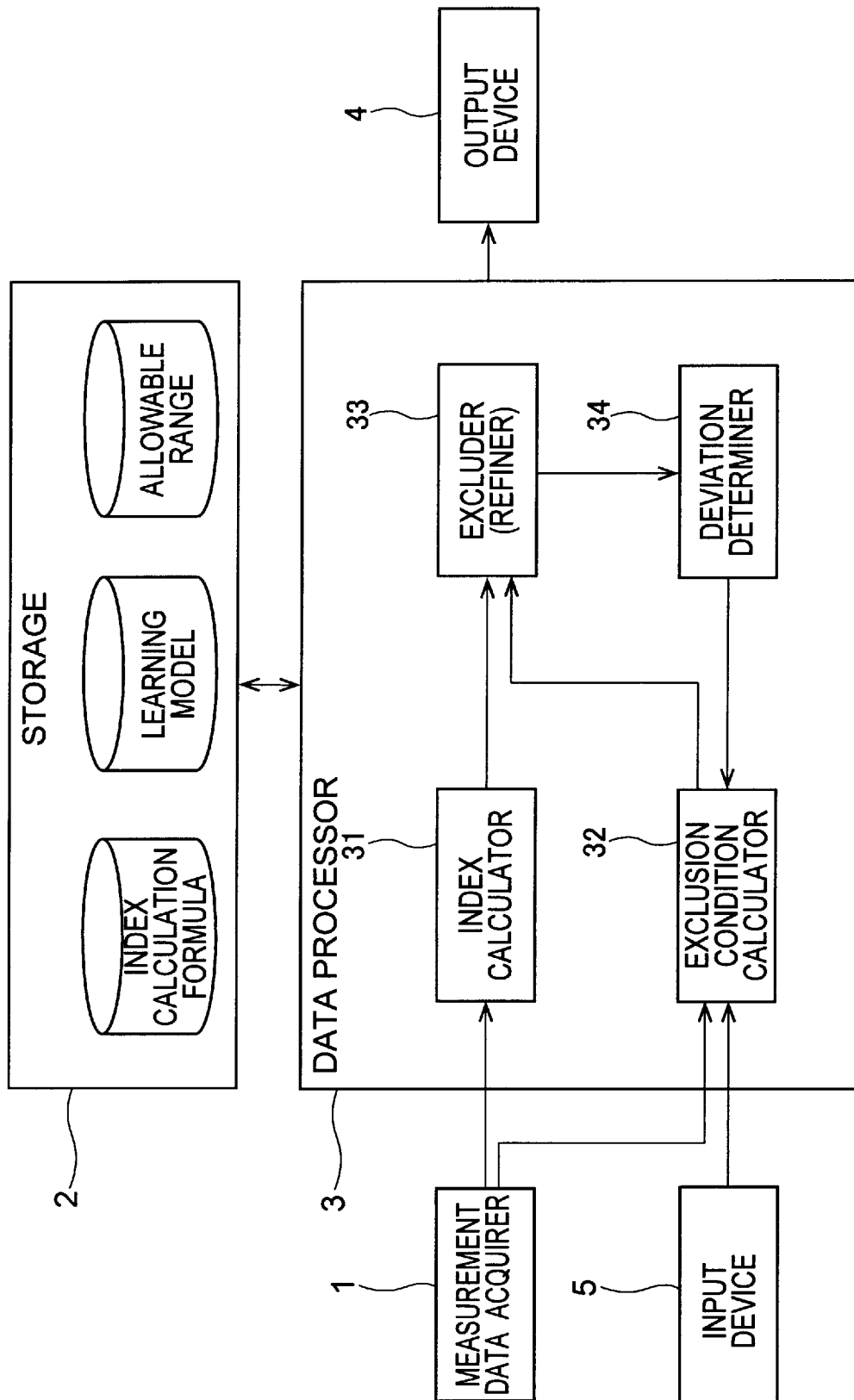
[Fig. 5]



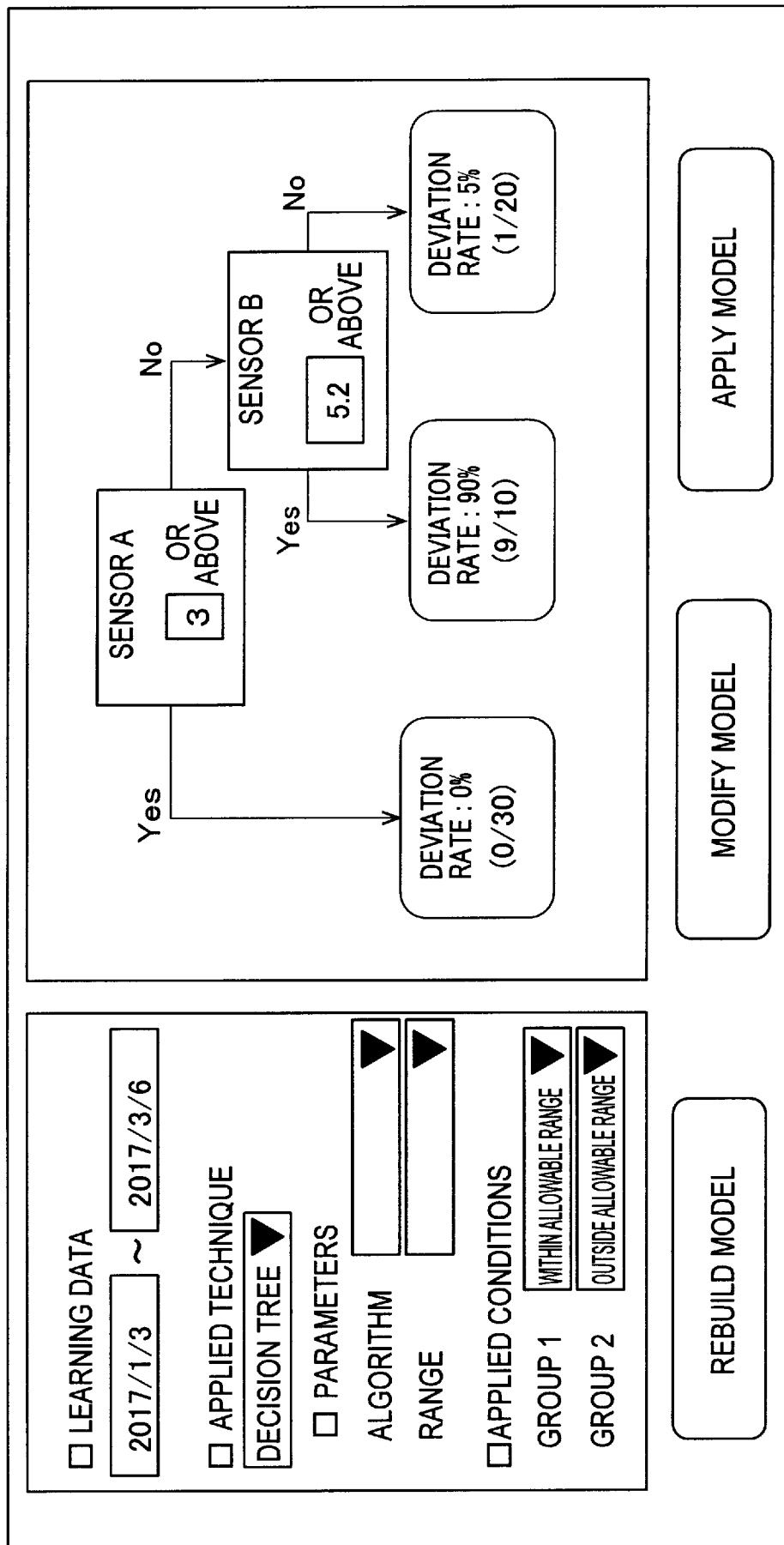
[Fig. 6]



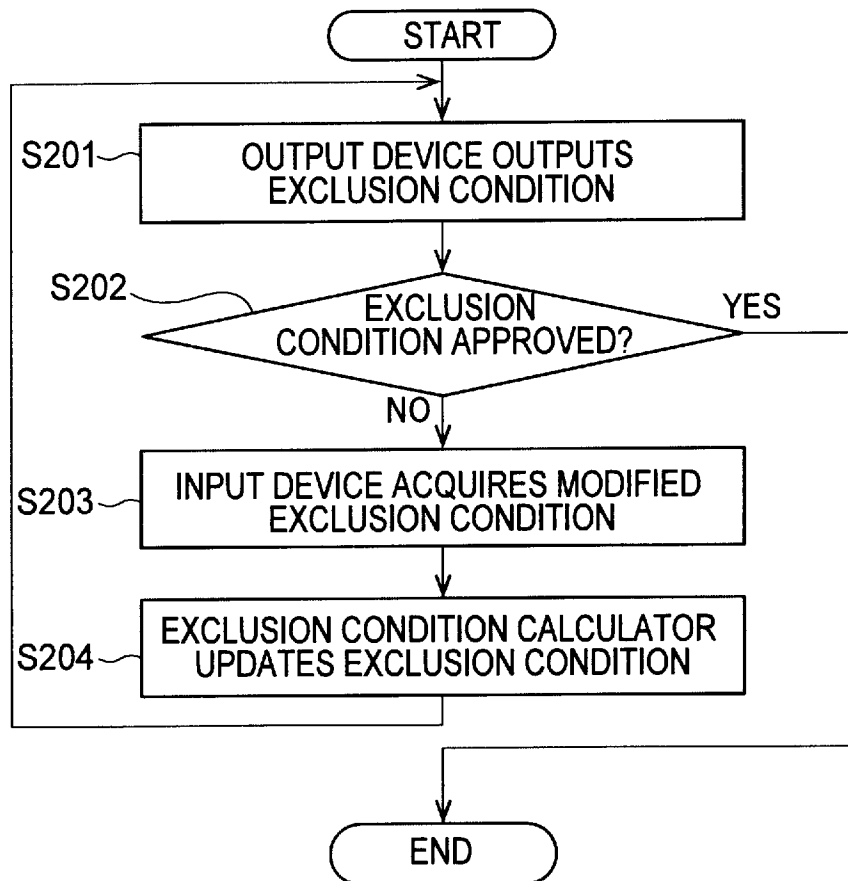
[Fig. 7]



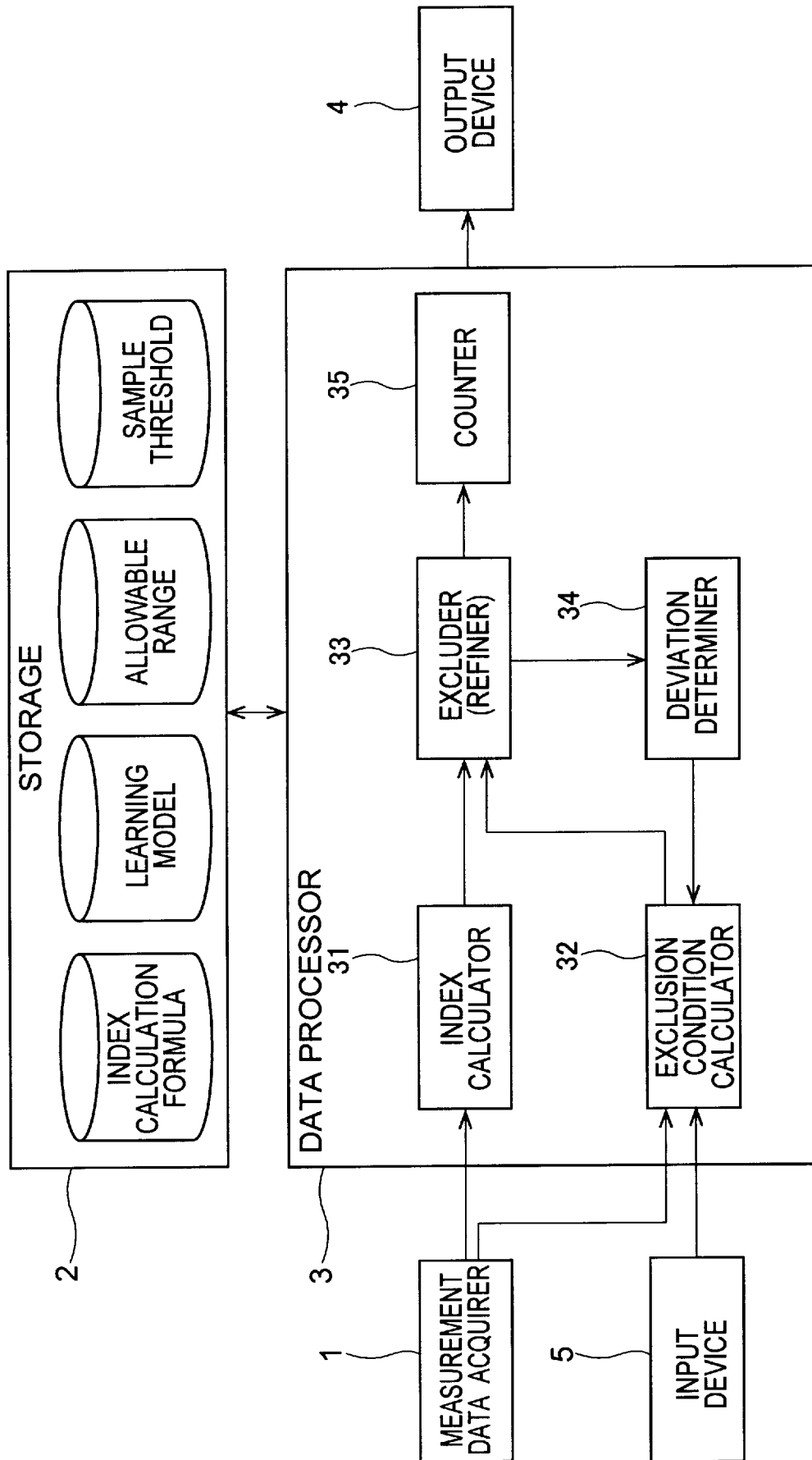
[Fig. 8]



[Fig. 9]



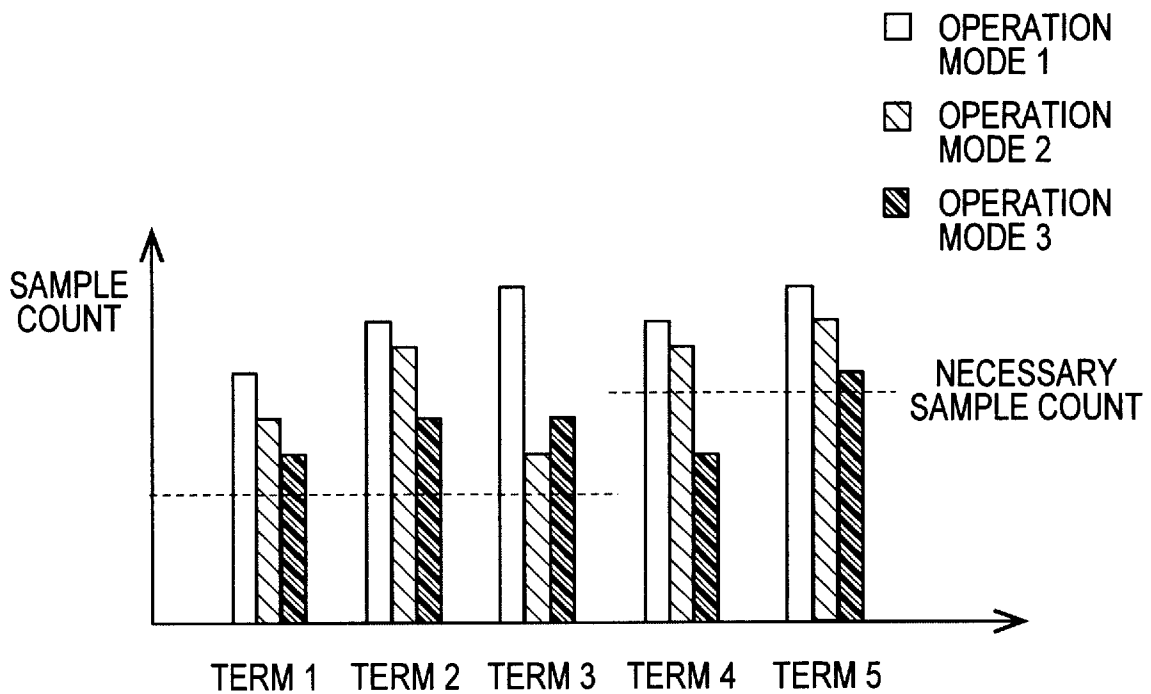
[Fig. 10]



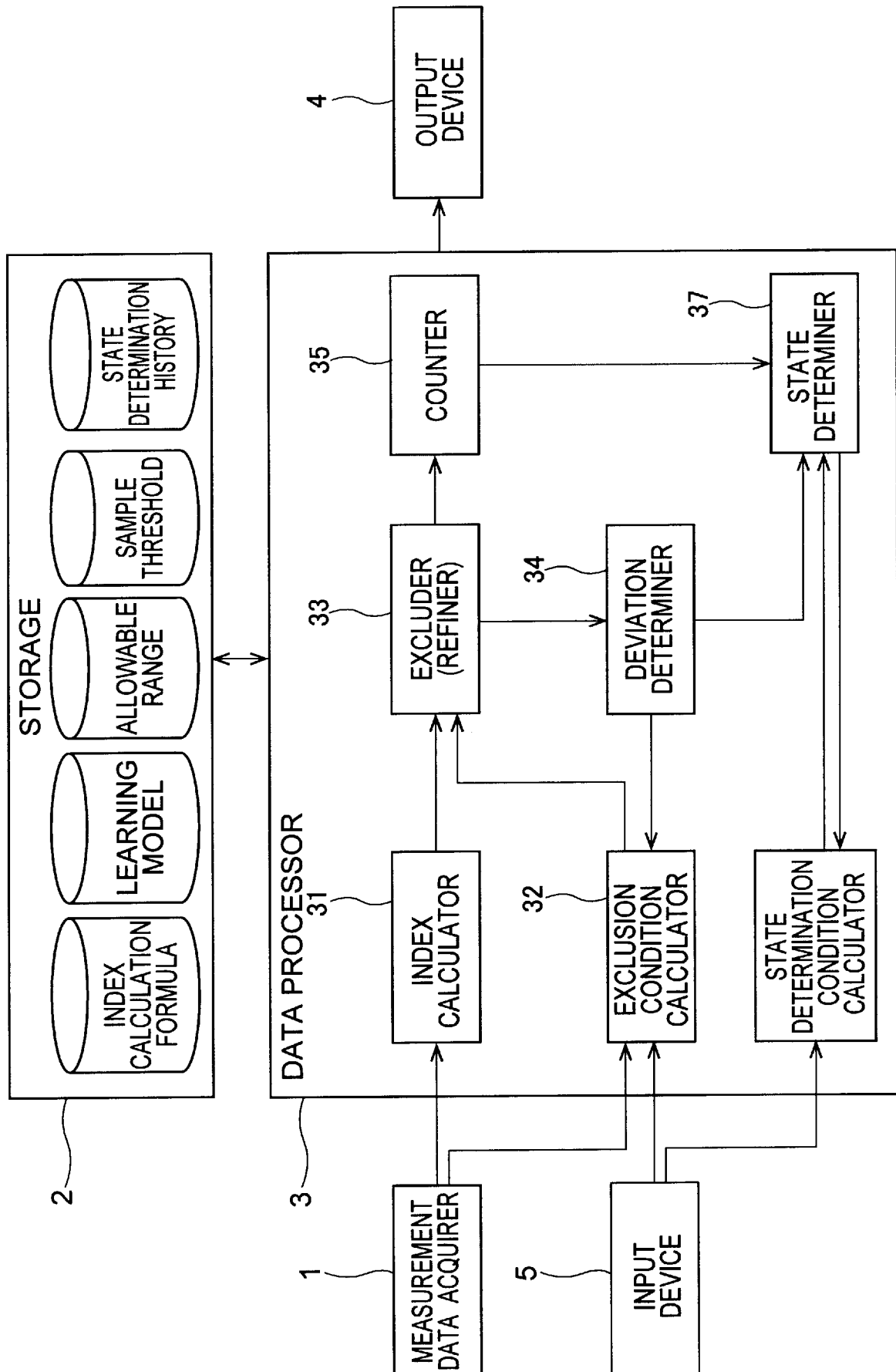
[Fig. 11]

	OPERATION MODE 1	OPERATION MODE 2	OPERATION MODE 3
TERM 1	50 (25)	40 (25)	30 (25)
TERM 2	60 (25)	55 (25)	40 (25)
TERM 3	70 (25)	30 (25)	40 (25)
TERM 4	60 (45)	55 (45)	30 (45)
TERM 5	70 (45)	60 (45)	50 (45)

[Fig. 12]



[Fig. 13]



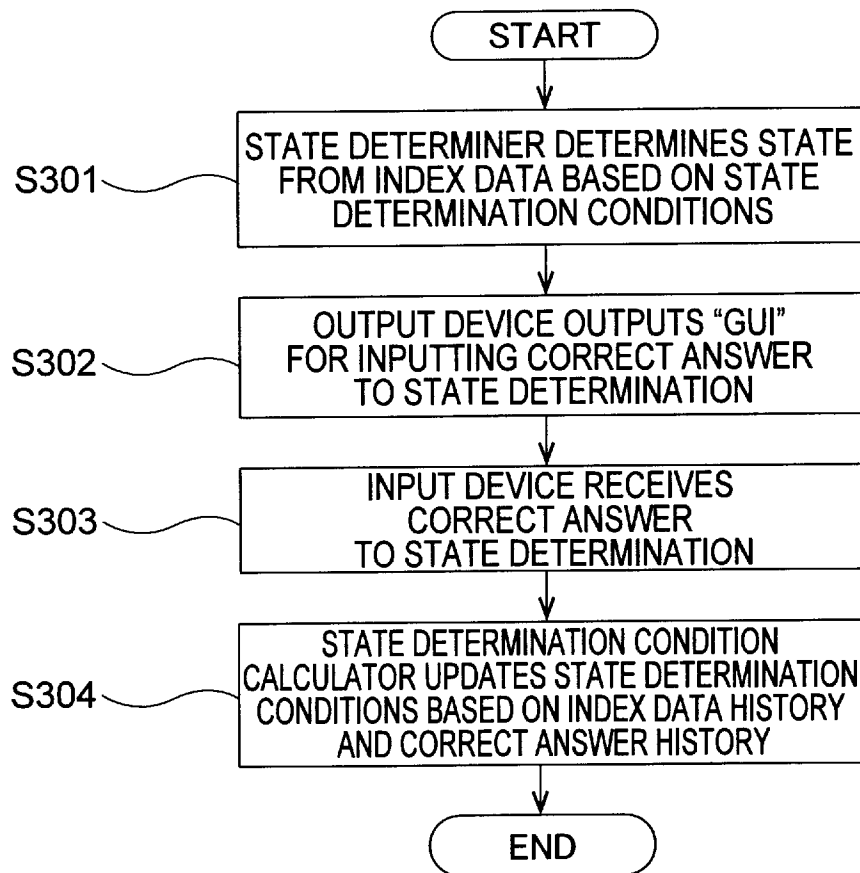
[Fig. 14]

DEVIATION RATE DISPLAY					SAMPLE COUNT DISPLAY				
	OPERATION MODE 1	OPERATION MODE 2	OPERATION MODE 3		OPERATION MODE 1	OPERATION MODE 2	OPERATION MODE 3		
TERM 1	10 ☒	6 ☐	3 ☐		50 ☐	40 ☐	30 ☐	TERM 1	
TERM 2	6 ☐	4 ☐	4 ☐		60 ☐	55 ☐	40 ☐	TERM 2	
TERM 3	7 ☐	3 ☐	3 ☐		70 ☐	30 ☐	40 ☐	TERM 3	
TERM 4	3 ☐	5 ☐	3 ☐		60 ☐	55 ☐	30 ☒	TERM 4	
TERM 5	5 ☐	6 ☐	2 ☐		70 ☐	60 ☐	50 ☐	TERM 5	
INSPECTION LABORSAVING AVAILABLE					INSPECTION LABORSAVING UNAVAILABLE				

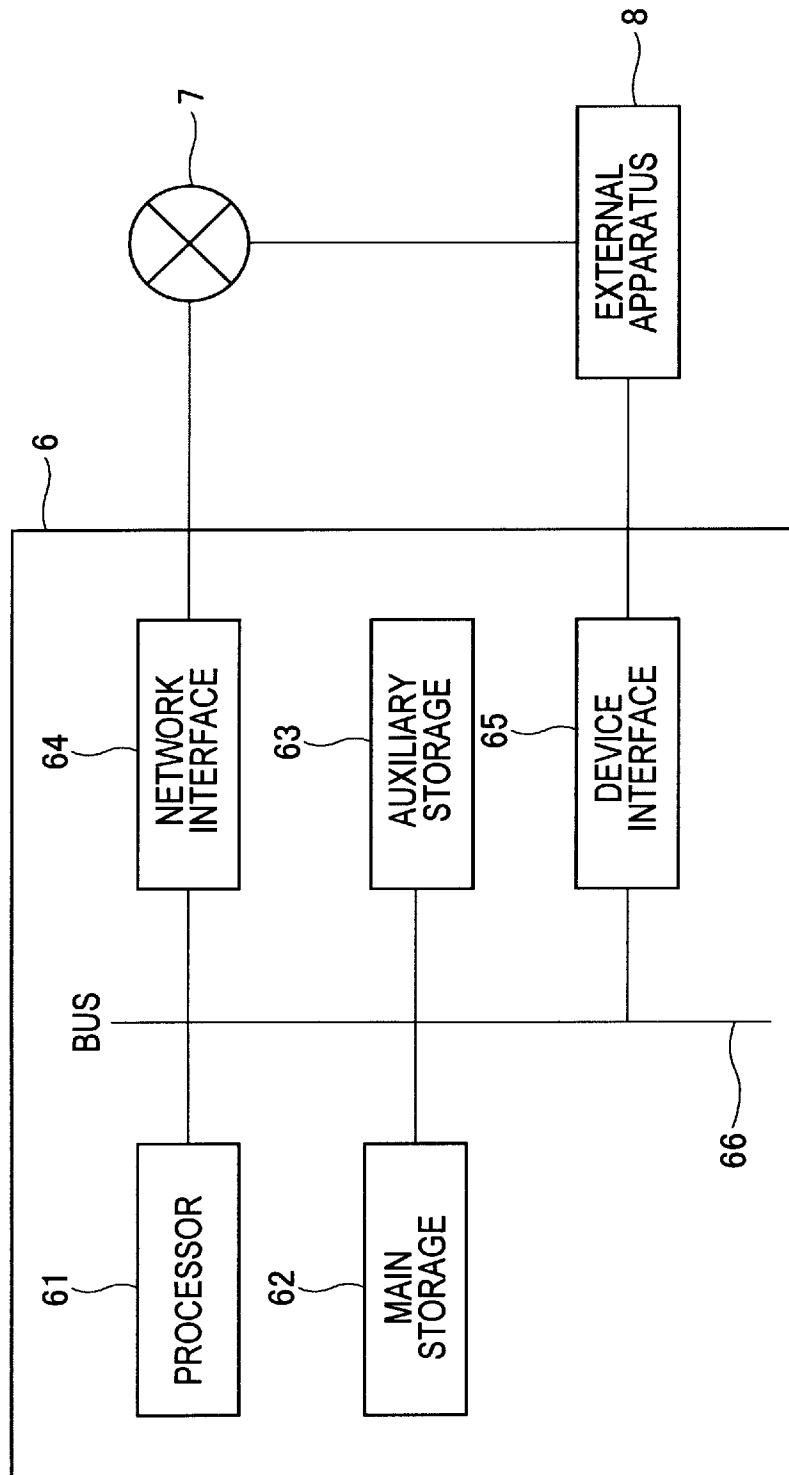
[Fig. 15]

DETERMINATION DATE/TIME	TERM	STATE	CLASS	THRESHOLD	DETERMINATION RESULT
17/3/6	TERM 1	OPERATION MODE 1	DEVIATION RATE	10 %	NG
17/3/6	TERM 1	OPERATION MODE 1	SAMPLE COUNT	50	OK
17/3/6	TERM 1	OPERATION MODE 2	DEVIATION RATE	6 %	OK
17/3/6	TERM 1	OPERATION MODE 2	SAMPLE COUNT	40	OK
17/3/6	TERM 1	OPERATION MODE 3	DEVIATION RATE	3 %	OK

[Fig. 16]



[Fig. 17]



INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2018/005888

A. CLASSIFICATION OF SUBJECT MATTER
INV. G05B23/02
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G05B

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	paragraph [0009] - paragraph [0010] paragraph [0048] - paragraph [0051] paragraph [0054] - paragraph [0055]; figure 3 paragraph [0059] - paragraph [0064]; figure 5	6
Y	----- WO 02/095633 A2 (SIMMONDS PRECISION PRODUCTS [US]) 28 November 2002 (2002-11-28) page 12, line 20 - page 13, line 18; figure 1 page 62, line 12 - page 63, line 5 ----- -/-	6



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

27 April 2018

Date of mailing of the international search report

11/05/2018

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Authorized officer

Bernard, Eddy

INTERNATIONAL SEARCH REPORT

International application No

PCT/JP2018/005888

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Information on patent family members

International application No

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