(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 2 600 103 B9**

(12) **CORRECTED EUROPEAN PATENT SPECIFICATION**

(15) Correction information:
Corrected version no 1 (W1 B1)
Corrections, see
Description **Paragraph(s) 65, 66, 67, 70, 71, 72, 74, 75, 76, 78, 79, 81, 82, 86, 87, 88, 89, 90, 91, 97, 100, 103, 104, 105, 107, 109, 111, 112, 116, 124, 128**

(48) Corrigendum issued on:
24.04.2019 Bulletin 2019/17

(45) Date of publication and mention of the grant of the patent:
12.09.2018 Bulletin 2018/37

(21) Application number: **11812117.7**

(22) Date of filing: **17.03.2011**

(51) Int Cl.:
G01B 11/02 *(2006.01)* ***G01C 25/00*** *(2006.01)*
G01B 21/04 *(2006.01)* ***G01S 17/48*** *(2006.01)*
G01C 3/06 *(2006.01)*

(86) International application number:
PCT/JP2011/056431

(87) International publication number:
WO 2012/014521 (02.02.2012 Gazette 2012/05)

(54) DISPLACEMENT SENSOR

VERSCHIEBUNGSSENSOR

CAPTEUR DE DÉPLACEMENT

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **30.07.2010 JP 2010172862**

(43) Date of publication of application:
05.06.2013 Bulletin 2013/23

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- **KAZUMASA TAKADA: "Improvement in Signal-to-Noise Ratio of Rayleigh Backscattering Measurement Using Optical Low Coherence Reflectometry", JOURNAL OF LIGHTWAVE TECHNOLOGY, IEEE SERVICE CENTER, NEW YORK, NY, US, vol. 20, no. 6, 1 June 2002 (2002-06-01), XP011064435, ISSN: 0733-8724**

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Description

TECHNICAL FIELD

[0001] The present invention relates to a displacement sensor for detecting an amount of displacement of an object through optical detection processing.

BACKGROUND ART

[0002] A displacement sensor based on principles of triangulation includes a light projecting unit including a light emitting element such as a laser diode and a light receiving unit including such a light receiving element as a PSD, a CCD, and a CMOS, and measures an amount of displacement based on a position in the light receiving unit where reflected light is incident while repeatedly performing processing for emitting light to an object to be detected from the light projecting unit and receiving at the light receiving unit, reflected light from the object to be detected (hereinafter referred to as "detection processing") and measurement processing for measuring an amount of displacement based on a result of reception of reflected light in a light receiving element.

[0003] Additionally, examples of a displacement sensor include a sensor to which a TOF (Time of Flight) method using a length of time from light projection to light reception is applied, a sensor to which a phase difference rangefinding method making use of a phase difference between projected light and received reflected light is applied, a sensor to which a PN code rangefinding method of projecting light of which intensity has been modulated with a PN code so as to conduct measurement using a result of correlation operation between that light and reflected light is applied, and the like.

[0004] Among these conventional displacement sensors, in order to stabilize detection, some sensors perform moving average calculation every time measurement data is obtained, by using that data and measurement data for a prescribed number of times in the past, and output an average value obtained in this calculation as detection data (see, for example, PTL 1).

[0005] In addition, PTL 1 discloses a displacement sensor having a function to set the number of pieces of data of moving average calculation above to a value suitable for obtaining accuracy demanded by a user through teaching processing by using a model of an object before main processing (see claim 6, paragraphs 0052 to 0057, and Fig. 6 of PTL 1).

[0006] Moreover, in order to conduct stable measurement with a displacement sensor, a time period for detection processing should be adjusted. For example, in a displacement sensor of a triangulation type, in order to clarify a peak of a light receiving amount signal generated by a light receiving unit, a light receiving amount signal having sufficient intensity should be obtained, however, intensity of a light receiving amount signal varies depending on a reflectance of a workpiece to be detected. Therefore, in the conventional displacement sensor, light emission intensity of a light emitting element or amplification gain of a light receiving amount signal is adjusted, and in addition, a time period for light projection processing or a time period required for both of light projection and light reception is adjusted in accordance with intensity of a light receiving amount signal (see, for example, paragraph 0021 of PTL 2).

[0007] Document XP011064453, "Improvement in Signal-to-Noise Ratio of Rayleigh Backscattering Measurement Using Optical Low Coherence Reflectometry" by Kazumasa Takada, published in the Journal of Lightwave Technology, ISSN 0733-8724, describes the improvement of the signal-to-noise ratio for increasing number of data used for averaging, and also mentions that from a practical point, in order to reduce the measurement time, a minimum number of data for averaging should be found that would still guarantee a sufficient signal-to-noise ratio.

CITATION LIST

PATENT LITERATURE

[0008]

PTL 1: Japanese Patent No. 3409117
PTL 2: Japanese Patent Laying-Open No. 2008-58195

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0009] Herein, in a displacement sensor providing step response, a time period from the time when detection processing is performed until output (including also display) reflecting an amount of displacement detected in that detection process-

ing ends will be referred to as a "response time". In a case where moving average calculation of measurement data is performed, a time period from the time when detection processing is performed until output of a result of final calculation in a plurality of times of moving average calculation using an amount of displacement detected in that detection processing corresponds to a response time.

[0010] Since a displacement sensor on which a high-speed CPU is mounted can perform measurement processing or moving average calculation in an extremely short period of time, a time period obtained by multiplying a processing time period necessary for detection processing once by the number of pieces of data to be subjected to moving average calculation can be considered as a time period substantially comparable to a response time.

[0011] In a case where a time period during which detection can be carried out is restricted, such as a case where a moving substance is to be detected, a length of a response time should be adjusted in accordance with the restricted time period. Though the number of pieces of data of moving average calculation should be decreased in order to shorten a response time, decrease in the number of pieces of data of moving average calculation may lead to poorer accuracy in detection data (error in detection data becomes great).

[0012] Namely, in adjustment of the number of pieces of data of moving average calculation, a response time and accuracy of detection data have trade-off relation.

[0013] A response time varies owing not only to the number of pieces of data of moving average calculation but also to a length of a processing time period for detection processing. Namely, in a case where the number of pieces of data of moving average calculation is fixed, a response time becomes longer as a processing time period is longer. In contrast, as the processing time period is shorter, the response time is also accordingly shorter.

[0014] On the other hand, accuracy of detection data is affected by an extent of variation in measurement data. Variation in measurement data fluctuates owing not only to capability of a sensor but also to a degree of ambient optical noise, a degree of asperity of an object to be detected, or the like.

[0015] At a site where a displacement sensor is used, the number of pieces of data of moving average calculation should be set in accordance with a production goal, a purpose of use of a displacement sensor, or the like at that site. For example, in a case where a displacement sensor is used for detecting difference in height in an article carried on a belt conveyor, it is necessary to set a target value for a response time such that an appropriate number of pieces of detection data is obtained while articles pass by a position where detection by a sensor is carried out and to find the number of pieces of data of moving average calculation such that the target value is achieved. In addition, it is also necessary to check whether or not a result of moving average calculation with that number of pieces of data satisfies accuracy required at the site.

[0016] A user, in particular a novice, at the site, however, is less likely to understand the concept of operation processing of moving average calculation or relation of influence by the number of pieces of data of moving average calculation on a response time or accuracy of detection data, and it may be difficult to make setting. In addition, since a processing time period or variation in measurement data suitable for detection processing fluctuates depending on a state of an object to be detected or a surrounding environment, it is also difficult to make such general setting as conforming to any instance. Therefore, most users at the site perform a setting operation through a trial and error process and hence users expend enormous efforts.

[0017] In connection with the problem above, in teaching processing described in PTL 1, user's designation of accuracy necessary for measurement processing is accepted, the number of pieces of data is variously changed to perform moving average calculation while detection processing and measurement processing for a model of an object are repeated, and the number of pieces of data as enabling variation in this result of calculation to adapt to designated accuracy is found. Burden imposed on the user can thus be mitigated. In this teaching processing described in PTL 1, however, the number of pieces of data of moving average calculation is determined only aiming to ensure detection accuracy without considering a length of a response time, and therefore this teaching processing is inadequate.

[0018] With attention being paid to the problems above, it is an object of the present invention to be able to automatically find through calculation and register a value of the number of pieces of data of moving average calculation necessary for ensuring a response time or accuracy of detection data at which a user aims, based on a result of detection processing or measurement processing on an actual model of an object to be detected.

SOLUTION TO PROBLEM

[0019] A displacement sensor according to the present invention is a displacement sensor according to claim 1.

[0020] According to the displacement sensor configured as above, as a teaching mode is started in such a manner that a model of an object to be detected is brought in correspondence with a position where it is irradiated with light from the sensor, the setting processing means performs each of detection processing and measurement processing a plurality of times, a processing time period for detection processing is set to an appropriate length, and variation in measurement data is derived. In addition, as at least one of a parameter representing a condition related to a response time and a parameter representing a condition related to accuracy of detection data is input, operation processing using that pa-

rameter value and a result of processing by the setting processing means is performed, the number of pieces of data of moving average calculation is derived, and this number of pieces of data can be registered with the registering means.

[0021] Therefore, as a user determines a condition related to a response time or accuracy of detection data in accordance with a purpose of use of a displacement sensor, a production goal at the site or the like, inputs parameters representing these conditions to a sensor, and executes the teaching mode, the number of pieces of data of moving average calculation suitable for satisfying the conditions above can automatically be derived by the sensor and registered.

[0022] In one preferred embodiment of the displacement sensor above, the input means inputs a numerical value representing a target value of the response time as the parameter representing conditions related to response time, and inputs a numerical value representing an error tolerance value of detection data as the parameter related to accuracy of the detection data.

[0023] In addition, the data number derivation means in this embodiment executes an operation using at least one of a first operational expression representing a relation among processing time of the detection process, the number of pieces of data of the moving average calculation and the response time, and a second operational expression representing a relation among the variation of measurement data, the number of pieces of data of the moving average calculation and the error of detection data, as the operation. For example, when a target value for a response time is input, the input value and the processing time period for detection processing adjusted by the setting processing means are substituted in the first operational expression, to thereby calculate the number of pieces of data of moving average calculation. Meanwhile, when an error tolerance value for detection data is input, the input value and variation in measurement data found by the setting processing means are substituted in the second operational expression, to thereby calculate the number of pieces of data of moving average calculation.

[0024] In a more preferred embodiment, when both the parameters representing the target value of the response time and the error tolerance value of detection data are input to the input means, the data number derivation means selects either one of the parameters with priority, executes a first operation of calculating the number of pieces of data of moving average calculation by applying the value input for the parameter and the result of processing by the setting processing means to the operational expression corresponding to the selected parameter, and thereafter executes a second operation by applying the number of pieces of data of moving average calculated by the first operation and the result of processing by the setting processing means to the operational expression corresponding to the non-selected parameter, to calculate the value of the parameter. The registration processing means determines whether or not the value of the non-selected parameter calculated by the second operation matches the value input to the input means, and when it is determined to be matching, registers the number of pieces of data of moving average calculated by the first operation with the registering means.

[0025] According to the embodiment above, in a case where the user inputs each parameter of a target value for a response time and an error tolerance value for detection data, the number of pieces of data of moving average calculation as adapting to the conditions represented by both of these parameters can be set and the number of pieces of data optimal for the condition represented by the parameter on which priority is placed can be set.

[0026] A parameter on which priority is to be placed here is desirably selected through a user's selection operation, however, for example, an operation of the data number derivation means may be defined such that priority is placed on a condition related to a response time. Alternatively, in a case where a parameter is selected in response to a user's selection operation, means for accepting that operation does not necessarily have to be provided in a sensor main body. For example, a device outside the sensor may accept a selection operation and a signal indicating a selection result may be input to the sensor.

[0027] The displacement sensor in yet another embodiment is provided with output means for outputting, when it is determined by the registration processing means that the value of the non-selected parameter calculated by the second operation does not match the value input to the input means, the value of the parameter calculated by the second operation for display. This output can be provided to a display unit provided in the sensor or an external device having a display unit.

[0028] According to the embodiment above, in a case where the number of pieces of data of moving average calculation is set based on a preferentially selected parameter and such setting results in failure in satisfying a condition designated by the user in connection with a parameter not selected, the user can be notified of magnitude of a value of the parameter not selected. Therefore, the user can take such measures as executing again the teaching mode, by correcting a parameter based on a value of which he/she has been notified to thereby fix the number of pieces of data of moving average calculation, or by referring to a value of which he/she has been notified to thereby change a value of each parameter.

[0029] Further, the displacement sensor in another preferred embodiment of the present invention is provided with signal input means for inputting a signal instructing start of processing in the teaching mode, and the setting processing means operates in response to an input of the signal. By doing so, as a signal is input to the signal input means while a model of an object to be detected is irradiated with light projected from the displacement sensor, that is, when detection processing is ready, data reflecting a result of processing on the object to be detected with regard to a processing time

period for detection processing or variation in measurement data can be obtained.

[0030] In the displacement sensor in a more preferred embodiment, the data derivation means and the registration processing means operate together with the setting processing means, every time the signal instructing start of processing is input. Further, in response to the input of the signal for the second time and onwards, the registration processing means determines an optimal value of the number of pieces of data of moving average, using the number of pieces of data derived from processing by the setting processing means and the data number derivation means in response to the input, and the number of pieces of data registered with the registering means in response to the signal input last time.

[0031] According to the embodiment above, in a case where a plurality of types of objects are to be detected or a plurality of parts different in reflectance are included in an object to be detected, every time a model of each object or each part in one model is successively brought in correspondence with a position where it is irradiated with light from the sensor, a signal supporting start of processing is input, so that the number of pieces of data of moving average calculation can be obtained for each model or each part. The registration processing means can set the number of pieces of data of moving average to an appropriate value in a range satisfying conditions for a response time or accuracy of detection data, by using every number of pieces of data.

[0032] As another embodiment in a case where processing of a plurality of types of objects or a plurality of parts different in reflectance is assumed, second signal input means for inputting a signal instructing end of processing in the teaching mode may be provided. In this embodiment, the setting processing means and the data number derivation means operate every time the signal instructing start of processing is input, and the registration processing means operates in responses to an input of the signal instructing end of processing. In addition, when the signal instructing start of processing is input a plurality of times before the signal instructing end of processing is input, the registration processing means determines an optimal value of the number of pieces of data of moving average, using the number of pieces of data of each moving average derived by the data number derivation means in response to every input of the signal.

[0033] In another embodiment in a case where second signal input means is provided, the setting processing means and the data number derivation means operate in response to an input of the signal instructing start of processing, and the registration processing means operates in responses to an input of the signal instructing end of processing. Further, the setting processing means and the data number derivation means are capable of executing processes a plurality of times from the input of the signal instructing start of processing until the input of the signal instructing end of processing. In addition, when a plurality of numbers of data of moving average are derived by the data number derivation means before the signal instructing end of processing is input, the registration processing means determines an optimal value of the number of pieces of data of moving average, using these numbers of data.

[0034] In the displacement sensor in the two embodiments above, an operation unit for generating the signal instructing start of processing and the signal instructing end of processing can be provided. In this case, the user can perform an operation to indicate start of processing while he/she confirms that the object to be detected or the part to be detected has been brought in correspondence with the position where it is irradiated with light from the sensor, and can perform an operation to indicate end in response to the fact that processing on all models or all parts has ended, so that an appropriate value for the number of pieces of data of moving average calculation can be determined and registered.

[0035] It is noted that a signal input to the signal input means is not limited to a signal generated by the operation unit above and a signal can also be input from an external device (a personal computer, a PLC, other sensors, etc.). For example, in a case where the teaching mode is executed while an object to be detected is being moved, the fact that a model of the object to be detected has entered an area of detection by the displacement sensor may be detected by another sensor or the like, that detection signal may be input as a signal indicating start of processing, and the setting processing means may be operated in response to that input.

[0036] A displacement sensor based on another point of view of the present invention, on the premise that it outputs detection data based on an average value obtained by moving average calculation while repeatedly executing a detection process of projecting light to an object and receiving the light reflected from the object, a measurement process of measuring an amount of displacement of the object based on the result of reception of the reflected light, and a moving average calculation of data of the measurement, includes registering means for registering the number of pieces of data of the moving average calculation, and teaching mode executing means for executing a teaching mode in which the number of pieces of data of the moving average calculation is registered with the registering means.

[0037] The teaching mode executing means includes setting processing means, specifying means, and registration processing means.

[0038] The setting processing means executes the detection process and the measurement process, each for a plurality of times, and executes a process for setting processing time of the detection process and a process of calculating variation of measurement data obtained by the measurement process.

[0039] The specifying means specifies a first function representing a relation between response time of the displacement sensor and the number of pieces of data of moving average calculation, based on processing time of the detection process set by the setting processing means, and specifies a second function representing a relation between an error

of detection data and the number of pieces of data of the moving average calculation based on the variation of measurement data calculated by the setting processing means. In addition, the specifying means specifies, based on these functions, at least one combination of the number of pieces of data of moving average, the response time corresponding to the number of pieces of data, and the error of detection data corresponding to the number of pieces of data.

[0040] The registration processing means displays the combination of response time and accuracy of detection data specified by the specifying means to be ready for a selection operation, and when any displayed combination is selected, registers the number of pieces of data of moving average corresponding to the selected combination with the registering means.

[0041] According to the displacement sensor configured as above, by executing the teaching mode with a model of an object being installed such that it is irradiated with light from the sensor, a processing time period for detection processing is set and variation in measurement data is found. In addition, using two functions specified based thereon, at least one combination of the number of pieces of data of moving average calculation with a response time and an error in detection data realized by that number of pieces of data is specified, and a response time and an error in detection data in each set are displayed. As the user selects combination that seems to be preferred in this display, the number of pieces of data of moving average calculation corresponding to the selected combination is registered with the registering means.

ADVANTAGEOUS EFFECTS OF INVENTION

[0042] According to the present invention, based on a result of detection processing or measurement processing on an actual model of an object to be detected, the number of pieces of data of moving average calculation can automatically be set to a value necessary for a response time or accuracy in detection data to satisfy a condition required by the user. Therefore, setting processing necessary for use of a displacement sensor can readily be performed without burden being imposed on the user.

BRIEF DESCRIPTION OF DRAWINGS

[0043]

Fig. 1 is a perspective view showing appearance of a sensor head of a displacement sensor.
Fig. 2 is a block diagram showing an electrical configuration of the displacement sensor.
Fig. 3 is a flowchart showing a procedure of teaching processing in a case where priority is placed on a response time.
Fig. 4 is a flowchart showing a procedure of teaching processing in a case where priority is placed on detection accuracy.
Fig. 5 is a flowchart showing a procedure of teaching processing in a case where a plurality of workpieces are of interest and priority is placed on a response time.
Fig. 6 is a graph exemplifying a function showing relation between a response time and the number of pieces of data of moving average calculation and a function showing relation between a detection error and the number of pieces of data of moving average calculation.

DESCRIPTION OF EMBODIMENTS

[0044] Fig. 1 shows appearance of a sensor head according to one embodiment of a displacement sensor to which the present invention is applied, and Fig. 2 shows an electrical configuration of the displacement sensor.

[0045] A displacement sensor 1 in this embodiment projects a laser beam L1 from a sensor head 10 onto a workpiece W to be detected, receives reflected light L2 of this laser beam L1 from workpiece W, and measures an amount of displacement of a surface of workpiece W based on principles of triangulation. It is noted that it is a distance from sensor head 10 that is measured as an amount of displacement, and a numerical value representing a distance can be output also as detection data. In addition, by registering in advance a distance to a reference plane such as a support plane of workpiece W, a measured distance can be replaced with a height when viewed from the reference plane, so that this height can also be output as detection data.

[0046] A light projecting unit 101, a light receiving unit 102, a CPU 110, a memory 111, and the like shown in Fig. 2 are incorporated in sensor head 10. In addition, though not shown, an auxiliary housing called an amplification portion is connected through a cable 11 to sensor head 10, and this amplification portion is provided with a display unit 121, an operation unit 122, an input/output interface 123, and the like shown in Fig. 2. It is noted that sensor head 10 and the amplification portion do not necessarily have to be separate from each other and all features shown in Fig. 2 may be provided in a single housing.

[0047] Light projecting unit 101 is provided not only with a laser diode (LD) as a light emitting element 103 but also

with a light projection control circuit 104. Light projection control circuit 104 drives light emitting element 103 while adjusting light emission intensity or a light emission time period of light emitting element 103 based on a command from CPU 110.

[0048] Light receiving unit 102 is provided with a CMOS as an imaging element 105 and also with a signal processing circuit 106 for processing an image signal generated by this imaging element 105 and an A/D conversion circuit 107. Signal processing circuit 106 controls timing of an operation of imaging element 105 based on a command from CPU 110, and takes in an image generated by imaging element 105 for output to A/D conversion circuit 107. An image resulting from digital conversion by A/D conversion circuit 107 is input to CPU 110 for measurement processing.

[0049] Memory 111 is a non-volatile memory such as an EEPROM, and it stores not only a program but also setting data for defining each operation of CPU 110, the number of pieces of data of moving average calculation derived in a teaching mode which will be described later, a maximum exposure time, and the like. In addition, in this memory 111, a function as a buffer for storing every measurement data for moving average calculation is also set.

[0050] CPU 110 causes light projecting unit 101 to emit laser beam L1 based on a program or setting data in memory 111 and causes light receiving unit 102 to operate in accordance with the timing of emission to thereby receive reflected light L2 from workpiece W. Thus, an image showing a state of reflected light L2 incident on imaging element 105 is generated.

[0051] Light projection processing and light reception processing above are hereinafter collectively referred to as "detection processing".

[0052] CPU 110 causes light projecting unit 101 and light receiving unit 102 to repeatedly perform detection processing, processes an image generated in every detection processing, and detects a reflected-light image in this image. Further, CPU 110 detects a coordinate of a position in the reflected-light image where a maximum light receiving amount is obtained (a peak of the light receiving amount), and measures an amount of displacement of workpiece W based on this coordinate.

[0053] In addition, in this embodiment, in order to stabilize output, moving average calculation of measurement data is performed, and an average value obtained in that calculation or a numerical value obtained by replacing this average value with a height when viewed from the reference plane described previously is displayed on display unit 121 as detection data.

[0054] Display unit 121 displays the detection data above, and also displays a numerical value input by the user, a provisionally set numerical value, and the like in the teaching mode which will be described later. Operation unit 122 is set to accept an operation to switch to the teaching mode and an operation to indicate start of teaching and also to accept an input of a parameter serving as a condition in teaching.

[0055] Input/output interface 123 is connected to an external device such as a personal computer or a PLC. When an external device is connected, a setting operation or an input operation similar to those performed through operation unit 122 above are performed in the external device and contents in the operation can be transmitted to CPU 110 in displacement sensor 1. In addition, a result of setting in the teaching mode and detection data obtained in a normal operation mode can also be output to the external device through input/output interface 123 and displayed thereon.

[0056] Further, in displacement sensor 1 in this embodiment, a function to adjust an exposure time based on intensity of every light receiving amount is set such that measurement processing on workpiece W can be performed in a stable manner. This adjustment processing is performed through cooperation among CPU 110, light projection control circuit 104, and signal processing circuit 106.

[0057] Here, an exposure time refers to a length of a period including a period during which light projecting unit 101 emits laser beam L1 and a period during which light receiving unit 102 receives reflected light L2. Though operation periods of light projecting unit 101 and light receiving unit 102 are made equal to each other in this embodiment, the embodiment is not limited as such. There is also a case of control where an operation period of light projecting unit 101 is set slightly longer than an operation period of light receiving unit 102 so that light reception processing by light receiving unit 110 is started after light projection from light projecting unit 110 is started and light projection processing ends after light reception processing ends. In addition, though rarely adopted, there is also a case where an operation period of light receiving unit 102 is longer than an operation period of light projecting unit 101.

[0058] The exposure time above is adjusted such that it is longer as a reflectance of workpiece W to be detected is lower. As the exposure time is longer, a cycle of obtaining every measurement data also becomes longer, which affects a length of a response time.

[0059] In addition, in image data generated by light receiving unit 102, fluctuation originating from capability of the sensor, ambient optical noise around the sensor, asperity or vibration of workpiece W (vibration being caused while workpiece W moves), or the like occurs. Such fluctuation leads to variation in measurement data, which in turn affects accuracy of detection data.

[0060] Further, since a result of moving average calculation is output as detection data in this embodiment, a response time varies also depending on the number of pieces of data of moving average calculation. Furthermore, detection accuracy also varies depending on the number of pieces of data of this moving average calculation.

[0061] Specifically, relation between a response time or detection accuracy and the number of pieces of data of moving average calculation is shown as an expression, as seen in Expression A and Expression B below.

<Expression A>

$$Response\ Time\ (RT) = \frac{Maximum}{Exposure\ Time}\ (ST) \times \frac{The\ Number\ of\ Pieces\ of}{Data\ of\ Moving\ Average\ Calculation}\ (N)$$

<Expression B>

$$Detection\ Error\ (D) = \frac{1}{\sqrt{\frac{The\ Number\ of\ Pieces\ of\ Data\ of}{Moving\ Average\ Calculation}\ (N)}} \times \frac{Variation\ in}{Measurement\ Data}\ (V)$$

[0062] "Maximum exposure time (ST)" in Expression A represents a maximum value of the exposure time set in processing for adjusting the exposure time. "Variation in measurement data (V)" in Expression B can be found, for example, as a difference between a maximum value and a minimum value in measurement data obtained in detection processing and associated measurement processing of a plurality of times. Alternatively, variance or standard deviation among measurement data can also be adopted as variation V. Alternatively, deviation between measurement data obtained in every measurement processing and immediately preceding measurement data may be obtained and a maximum value in deviations obtained in the past may be adopted as variation V (for example, an initial value for V is assumed as 0, and each time deviation greater than V is obtained, a value for V is overwritten with that deviation).

[0063] With the displacement sensor in this embodiment, as a result of a user's mode switching operation, the teaching mode for registering the number of pieces of data N of moving average calculation can be executed. In utilizing this teaching mode, the user inputs at least one of a value that seems to be preferred as a response time RT (a target value) and a value tolerable as a detection error D (a tolerance value), installs an actual model of workpiece W to be detected (hereinafter referred to as a "workpiece model") directly under sensor head 10, and performs an operation to start teaching by using operation unit 122 or an external device. Thus, detection processing or measurement processing on the workpiece model is performed, maximum exposure time ST is determined, and variation in measurement data V is calculated. In addition, based on Expression A and Expression B in which each value for ST and V is substituted, a numerical value necessary for satisfying a condition represented by a target value or a tolerance value input by the user is derived as the number of pieces of data N of moving average calculation. The derived number of pieces of data N is displayed on display unit 121 and registered in memory 111.

[0064] When registration processing above is completed and switching from the teaching mode to the normal operation mode is made, CPU 110 reads, every time, N pieces of measurement data in total retroactively from most recent measurement data while it performs detection processing and measurement processing, and calculates an average value thereof. Then, the calculated average value or a value obtained by replacing this average value with data of a height when viewed from the reference plane is output as detection data.

[0065] In the teaching mode in this embodiment, a target value RT0 for a response time can be input as a parameter representing a condition related to a response time, and a tolerance value D0 for detection error can be input as a parameter representing a condition related to detection accuracy. As shown in Expression A and Expression B, however, these conditions have trade-off relation. Therefore, in this embodiment, such a state that priority is placed on a condition related to response time RT is adopted as default setting, and in a case where a condition related to detection accuracy is also input, initially based on Expression A, a value necessary for setting response time RT to a value close to target value RT0 is calculated assuming the number of pieces of data of moving average calculation as N, and thereafter whether or not detection error D caused in moving average calculation with the number of pieces of data being N is equal to or smaller than tolerance value D0 input by the user is determined based on Expression B. Here, when detection error D is equal to or smaller than tolerance value D0, the number of pieces of data N is registered.

[0066] On the other hand, when detection error D with the number of pieces of data being N exceeds tolerance value D0 input by the user, the number of pieces of data N is not registered. When difference from tolerance value D0 is small (which is determined based on a threshold value $\delta 1$ which will be described later), however, the number of pieces of data N can also be registered through a correction operation which will be described later.

[0067] Fig. 3 shows a processing procedure in the teaching mode in accordance with the default setting above. This processing procedure is applied to a case where both of target value RT0 for a response time and tolerance value D0 for detection error are input under the default setting and also to a case where only target value RT0 for a response time is input.

[0068] In addition, this processing procedure is on the premise that a user installs a workpiece model such that laser beam L1 is appropriately emitted downward of sensor head 10 and thereafter an operation to indicate start of processing is performed. As this operation is performed, determination as "YES" is made in step S1 and detection processing by light projecting unit 101 and light receiving unit 102 is started (step S2).

[0069] Though not clearly shown in Fig. 3, detection processing is repeatedly performed also subsequently. In addition, each time detection processing is performed, an exposure time is adjusted based on intensity (a peak value of the light receiving amount or an integral value of the light receiving amounts in the entire reflected light image) of reflected light L2 shown in the image from light receiving unit 102 and that exposure time is applied to next detection processing. In this example, with a period until the exposure time is stabilized being defined as step S3, maximum exposure time ST is determined from every exposure time. Though the exposure time is adjusted continually also in subsequent detection processing, adjustment thereof is made in a range not exceeding maximum exposure time ST.

[0070] In step S4, value RT0 input as the target value for the response time and maximum exposure time ST determined in step S3 are substituted into Expression A and this Expression A is executed, to thereby calculate the number of pieces of data N of moving average calculation. It is noted that N is an integer and if digits to the right of a decimal point are included in a result of calculation, these values are dropped. In addition, in consideration of influence by a time period for measurement processing or moving average calculation, the number of pieces of data N may be corrected to a value slightly smaller than the calculated value.

[0071] When the calculated value for N is equal to or greater than 1 ("YES" in step S5), whether tolerance value D0 for the detection error has been input or not is checked. When D0 has not been input ("NO" in step S6), the number of pieces of data N calculated in calculation above is displayed on display unit 121 and registered in memory 111, and the process ends here.

[0072] On the other hand, when tolerance value D0 for the detection error has been input ("YES" in step S6), the process proceeds to step S7, in which detection processing and measurement processing are performed a plurality of times and variation in measurement data V obtained in the processing is calculated.

[0073] Though measurement processing is performed at the time point of processing in step S7 so as to find variation in measurement data V in this example, the processing is not limited as such. Measurement processing may also be started when detection processing is started in step S2 and variation in measurement data V may be found in parallel to processing for adjusting an exposure time. It is noted that variation V in this case will be a slightly rough value.

[0074] Then, in step S8, variation in measurement data V and the number of pieces of data N found in step S4 are substituted in Expression B to thereby calculate detection error D, and this detection error D is compared with tolerance value D0 input by the user (step S9). When D is equal to or smaller than D0 here ("YES" in step S9), the process proceeds to step S10, in which the number of pieces of data N is displayed and registered, and the process ends.

[0075] When calculated detection error D is greater than D0 ("NO" in step S9), a difference therebetween is compared with predetermined threshold value $\delta 1$. When a value of difference is equal to or smaller than $\delta 1$, a value for detection error D is displayed on display unit 121 (step S11).

[0076] Here, when an operation to correct tolerance value D0 to D is performed with an assumption that the user will accept a value for detection error D ("YES" in step S13), the process proceeds to step S10. Thus, the number of pieces of data N calculated in step S4 is displayed and registered.

[0077] On the other hand, when an operation to cancel is performed with an assumption that the user will not accept a displayed value for tolerance value D ("NO" in step S13), the process proceeds to step S14, in which display on display unit 121 is switched to error indication, and the process ends.

[0078] It is noted that more detailed display may be provided in step S10 or step S14. For example, in step S10, together with the number of pieces of data N, each value of maximum exposure time ST, variation in measurement data V, and detection error D can be displayed. In step S14, in addition to a message indicating an error, the calculated number of pieces of data N can be displayed or display associating detection error D and tolerance value D0 with each other can be provided. In a case where such detailed display is provided, display on an external device may be adopted.

[0079] According to the processing above, since a value necessary for setting response time RT to a length close to target value RT0 input by the user can automatically be derived as the number of pieces of data N of moving average calculation, the derived number of pieces of data N can promptly be registered in a case where the user has not designated tolerance value D0 for detection error. In addition, even in a case where tolerance value D0 for detection accuracy is input, when detection accuracy D realized by the derived number of pieces of data N is equal to or smaller than tolerance value D0, the number of pieces of data N can promptly be registered.

[0080] Therefore, the user determines a condition in accordance with a production goal at the site, a purpose of use of the displacement sensor, or the like in connection with at least the response time of response time RT and detection error D and inputs a numerical value representing that condition, so that the number of pieces of data N most suitable for the condition determined by the user can automatically be derived and registered within the sensor's capability. Therefore, even a user who does not understand well the concept of moving average calculation or influence by the number of pieces of data N used in this calculation on a response time or detection accuracy can make setting optimal

for operating the displacement sensor in order to satisfy the condition determined by the user himself/herself.

[0081] In addition, even in a case where the user cannot obtain desired detection accuracy with the derived number of pieces of data N, when detection error D that can be realized is not considerably distant from tolerance value D0 and the user can accept detection error D, the calculated number of pieces of data N can be registered by performing an operation to correct tolerance value D0 to D. Thus, convenience of the sensor can be enhanced.

[0082] Moreover, according to the processing in Fig. 3, when difference between calculated measurement error D and tolerance value D0 is greater than $\delta 1$ ("NO" in step S11) or when the number of pieces of data N calculated in step S4 is smaller than 1 (step S5), an error indication (step S14) is given. Therefore, when the number of pieces of data N cannot ensure accuracy desired by the user or when the user's desired condition cannot be fulfilled with the sensor's capability, registration of the number of pieces of data at an inappropriate value can be prevented.

[0083] Further, in the teaching processing above, maximum exposure time ST determined in step S3 is desirably registered together with the number of pieces of data N. This is because, by registering maximum exposure time ST, in adjusting an exposure time in the normal operation mode, an adjusted value can be controlled not to exceed maximum exposure time ST and an actual response time can reliably be not greater than target value R0.

[0084] It is noted that registration of maximum exposure time ST is not essential. This is because, if an exposure time is well adjusted in the teaching processing and then maximum exposure time ST is determined, an exposure time in the normal operation mode will also be within a range below maximum exposure time ST.

[0085] Under the default setting above, priority is placed on the response time of response time RT and detection error D, however, the user can also change setting so as to place priority on detection error D. Fig. 4 shows a processing procedure in a case where this setting is changed.

[0086] In this processing, such a premise is made that the user inputs at least tolerance value D0 for detection error and installs a workpiece model at a position where it is irradiated with laser beam L1 and then a start indication operation is performed. When the start indication operation is performed ("YES" in step S101), detection processing is started as in steps S2 to S4 in Fig. 3 and maximum exposure time ST is determined (steps S102, S103). In addition, variation in measurement data V is calculated (step S104).

[0087] Then, tolerance value D0 for detection error and variation V calculated in step S104 are substituted into Expression B to thereby calculate the number of pieces of data N of moving average calculation (step S105). It is noted that, in a case where numerical values to the right of the decimal point are included in this result of calculation, such numerical values are rounded up. In addition, in order to reliably suppress a detection error to tolerance value D0 or smaller, a calculated value for the number of pieces of data N may be corrected to a value to which a small value has been added.

[0088] When the value for N calculated in the processing above is equal to or greater than 1 ("YES" in step S106), whether target value RT0 for a response time has been input or not is checked. When target value RT0 has not been input, the process proceeds to step S110, in which the number of pieces of data N is displayed on display unit 121 and registered in memory 111, and the process ends.

[0089] When target value RT0 has been input ("YES" in step S107), the number of pieces of data N calculated in calculation above and maximum exposure time ST determined in step S103 are substituted into Expression A to thereby calculate response time RT (step S108), and this value for RT is compared with target value RT0 input by the user (step S109). Here, when RT is equal to or smaller than RT0 ("YES" in step S109), the process proceeds to step S110, in which the number of pieces of data N is displayed and registered, and the process ends.

[0090] On the other hand, when calculated response time RT exceeds target value RT0 ("NO" in step S109), difference therebetween is compared in step S111 with a predetermined threshold value $\delta 2$. When a value for this difference is equal to or smaller than $\delta 2$ ("YES" in step S111), a value for response time RT is displayed (step S112). When the user performs an operation to correct target value RT0 to RT in this display ("YES" in step S113), transition to step S110 is made and the number of pieces of data N is displayed and registered. On the other hand, when the user performs an operation to cancel without performing a correction operation ("NO" in step S113), display on display unit 121 is switched to an error indication in step S114 and thereafter the process ends.

[0091] When a difference between response time RT and target value RT0 above exceeds $\delta 2$ ("NO" in step S111) or when the number of pieces of data N calculated in step S105 is smaller than 1 ("NO" in step S106) as well, an error indication in step S114 is provided.

[0092] It is noted that more detailed display can be provided also in step S110 or step S114 in Fig. 4, as set forth in connection with step S10 or step S14 in Fig. 3.

[0093] In addition, in the examples in Figs. 3 and 4, conditions of both of a response time and detection accuracy are specifically designated and when the number of pieces of data N derived based on a condition on which priority was placed could not satisfy the other condition on which priority was not placed, criteria for the condition on which priority was not placed are lowered to allow registration of the number of pieces of data N, however, the example is not limited as such. When neither of the conditions can be satisfied, an error indication may always be provided.

[0094] On the other hand, instead of setting the number of pieces of data N to an optimal value for the condition on

which priority was placed as in the examples in Figs. 3 and 4, the number of pieces of data N may be corrected such that a condition represented by a parameter on which priority was not placed is satisfied. In that case, however, an amount of correction is desirably limited within a certain numerical range. In addition, together with the corrected number of pieces of data, a value for a response time or detection accuracy realized by the number of pieces of data is desirably displayed.

[0095] The processing procedure in Figs. 3 and 4 assumes a case where the number of types of workpieces to be detected is one, however, depending on a site, there is also a case where a plurality of types of workpieces are to be processed by a single displacement sensor. Taking into consideration this aspect, the teaching mode of displacement sensor 1 above includes also a procedure for teaching processing in a case where a plurality of types of workpieces are of interest.

[0096] In the teaching processing in which a plurality of types of workpieces are of interest, the user prepares a workpiece model for each workpiece, successively sets these workpiece models at a position where each one is irradiated with laser beam L1, and performs a start indication operation. In addition, the user finally performs an operation to indicate end of the teaching processing. Each time the start indication operation is performed, CPU 110 determines maximum exposure time ST in response to that operation and calculates the number of pieces of data N of moving average calculation in accordance with a condition represented by an input parameter. Then, in response to an operation to indicate end, one of values for the derived numbers of pieces of data N is selected and registered in memory 111.

[0097] Fig. 5 shows an example of a processing procedure in the teaching processing in which a plurality of types of workpieces are of interest. It is noted that, in this example, it is assumed that default setting with priority being placed on a response time is applied. In addition, for simplification of description, only a procedure in a case where both of target value RT0 for a response time and tolerance value D0 for detection error are input is shown. Moreover, in this example, when the derived number of pieces of data does not satisfy a condition represented by these input values, an error indication (step S217) is always given.

[0098] Description will be given hereinafter with reference to Fig. 5.

[0099] In this processing, a counter i indicating the number of workpiece models is set to an initial value 0 in a first step S201, and the start indication operation is awaited. When the start indication operation is performed ("YES" in step S202), detection processing is started (step S203), and each time detection processing is performed, a maximum exposure time STi is determined while the exposure time is adjusted based on intensity of the light receiving amount (step S204).

[0100] Then, in step S205, target value RT0 for a response time and maximum exposure time STi determined in step S204 are substituted into Expression A to thereby calculate the number of pieces of data Ni in moving average calculation. In successive step S206, detection processing and measurement processing are performed sufficient times, to thereby calculate variation in measurement data Vi obtained in measurement processing. It is noted that this variation Vi can also be found in parallel to processing in step S204.

[0101] Thereafter, maximum exposure time STi and the number of pieces of data Ni found in the processing above as well as variation in measurement data Vi are stored in memory 111 (step S207). Then, counter i is incremented (step S208).

[0102] When an end indication operation is performed after a loop of steps S202 to 208 above is performed at least once, determination as "YES" is made in each of step S209 and step S210 and the process proceeds to step S211. In step S211, a minimum value N_{MIN} in the number(s) of pieces of data stored while the loop of steps S202 to 208 is repeated is specified.

[0103] When minimum value N_{MIN} above is equal to or greater than 1 ("YES" in step S212), a maximum value V_{MAX} in variation in measurement data calculated in step S206 is specified (step S213). Then, this V_{MAX} and minimum value N_{MIN} of the number(s) of pieces of data specified in step S211 are substituted into Expression B to thereby calculate detection error D (step S214), and the calculated value is compared with tolerance value D0 (step S215).

[0104] When detection error D is equal to or smaller than tolerance value D0 ("YES" in step S215), minimum value N_{MIN} above is displayed as the number of pieces of data to be registered and the number of pieces of data is registered in the memory (step S216). Then, the maximum exposure time used for calculation at the time when the number of pieces of data N_{MIN} was derived is registered in memory 111 (step S217) and the process ends.

[0105] When detection error D exceeds tolerance value D0 ("NO" in step S215), an error indication (step S218) is given regardless of conditions, however, without being limited as such, processing the same as in steps S11 to S13 in Fig. 3 may be performed.

[0106] When the end indication operation is performed without the start indication operation being performed, i=0 is satisfied. Therefore, determination as "NO" is made in step S210 and the process proceeds to step S218, in which display unit 122 is switched to error indication. When the start indication operation was performed only once, the process proceeds to step S211, however, the processing hereafter in this case will substantially be similar to processing performed in each step of S5 and subsequent steps in Fig. 3.

[0107] As described above, in the processing procedure in Fig. 5, after maximum exposure time STi and the number

of pieces of data Ni in moving average calculation are found for each workpiece, minimum value N_{MIN} in every number of pieces of data Ni is registered and then the maximum exposure time used in calculation at the time when this minimum value N_{MIN} was obtained is registered. This is because, in a case where response time RT being not greater than target value RT0 is defined as a condition, such an operation as being able to satisfy the condition above should be defined, with a workpiece longest in time required for detection processing among the plurality of types of workpieces (a workpiece lowest in reflectance) serving as the reference.

[0108] When the teaching processing above ends and the mode returns to the normal operation mode, in subsequent detection processing, every exposure time is adjusted within a range up to the registered maximum exposure time and the registered number of pieces of data is used for performing moving average calculation. As a result of this control, even in a case where any of the plurality of types of workpieces is to be detected, an exposure time can be adjusted in accordance with a reflectance of that workpiece, and response time RT can be not greater than target value R0 based on the exposure time and the registered number of pieces of data.

[0109] In addition, according to the number of pieces of data registered in the processing shown in Fig. 5, whichever of the plurality of types of workpieces may be processed, detection error D can be suppressed to tolerance value D0 or smaller as input by the user.

[0110] Though teaching processing in a case where priority is placed on a condition related to detection accuracy rather than a condition related to a response time is not shown, in this case as well, a procedure from a point of view the same as in Fig. 5 above is performed.

[0111] Briefly speaking, as in Fig. 5, each time the start indication operation is performed, detection processing is performed to determine maximum exposure time STi, and variation in measurement data Vi is calculated. Then, Expression B into which variation Vi and tolerance value D0 for detection error are substituted is used to find the number of pieces of data Ni in moving average calculation necessary for detection error D to be equal to or smaller than tolerance value D0.

[0112] When processing for all workpiece models ends, a maximum value N_{MAX} in the number of pieces of data Ni found for each workpiece model is selected such that detection error D can be not greater than tolerance value D0 for any workpiece. In addition, a maximum value ST_{MAX} in the maximum exposure time found for each workpiece model is specified, and response time RT is calculated by substituting N_{MAX} and ST_{MAX} into Expression A. Then, when this response time RT is equal to or smaller than target value RT0, the number of pieces of data N_{MAX} is registered in memory 111.

[0113] As described above, in a case where a plurality of types of workpieces different in reflectance are to be detected, whichever workpiece may be processed, the number of pieces of data corresponding to the most strict criteria is desirably selected from among the numbers of pieces of data derived for the workpieces in order to be able to ensure the condition designated by the user. The selected number of pieces of data, however, does not necessarily have to be registered as it is. For example, when priority is placed on a condition related to a response time, a minimum value in the number of pieces of data found for each workpiece may be selected and thereafter a value further smaller than the minimum value (note that a value not smaller than 1) may be registered. Alternatively, when priority is placed on tolerance value D for detection accuracy, a maximum value in the number of pieces of data found for each workpiece is selected, however, a value further greater than the maximum value may be registered.

[0114] In addition, the teaching processing in a case where a plurality of types of workpieces are to be detected is also applicable to teaching processing in a case where a workpiece including a plurality of parts different in reflectance is to be detected.

[0115] In the processing described above, the optimal number of pieces of data of moving average calculation is found and registered in response to the fact that the end indication operation has been performed, however, the processing is not limited thereto. Each time the start indication operation is performed in the teaching mode, the number of pieces of data derived in response to that operation and the number of pieces of data that has been registered by that time point may be used to determine the optimal number of pieces of data, with which the registered data may be overwritten. For example, if the setting is such that priority is placed on a response time, the registered data can be overwritten with the newly derived number of pieces of data when the number of pieces of data derived in response to the new start indication operation is smaller than the registered number of pieces of data. Alternatively, if the setting is such that priority is placed on detection accuracy, the registered data can be overwritten with the newly derived number of pieces of data when the newly derived number of pieces of data is greater than the registered number of pieces of data. Alternatively, processing for deriving the number of pieces of data of moving average calculation may be performed a plurality of times during a period until the end indication operation is performed with the start indication operation being limited to once that is first performed, an optimal value may be selected from the numbers of pieces of data obtained in the plurality of times of processing in response to the fact that the end indication operation has been performed, and that value may be registered.

[0116] As described so far, in the teaching mode of displacement sensor 1 in this embodiment, such a premise is made that the user inputs at least one of target value RT0 for a response time and tolerance value D0 for detection error

and installs a workpiece model at a position where it is irradiated with laser beam L1 and then the start indication operation is performed. These inputs and start indication operation can be performed through the operation unit and also through an external device such as a personal computer. In addition, audio guidance may be provided for these operations.

[0117] In a case where workpieces continuously carried on a belt conveyor or the like are to be detected by displacement sensor 1, there is a demand also for performing teaching processing while workpiece models are being carried, similarly to during use. In this case, the start indication operation should only be performed at the timing when a workpiece model is irradiated with laser beam L1 while workpiece models are being carried, however, with other methods, a signal indicating start of processing may automatically be input or a time to start processing of a workpiece model may be recognized by CPU 110 in displacement sensor 1.

[0118] For example, such detection means as a photoelectric switch or a proximity switch can be provided at a position upstream of displacement sensor 1 in a path for carrying workpieces so that a signal from the detection means can be input instead of the start indication operation. Meanwhile, in a case where a plurality of types of workpieces are to be detected, an RFID tag storing a type or the like of a workpiece may be attached to each workpiece and an RFID reader-writer may be provided as detection means.

[0119] Alternatively, CPU 110 in displacement sensor 1 may repeat detection processing and processing for finding deviation of a light receiving amount obtained in every detection processing from an immediately preceding light receiving amount, and may determine the time when the deviation exceeds a threshold value set in advance as the time to start processing on a workpiece model. Alternatively, in a case where a distance from sensor head 10 to a workpiece support surface is registered as a reference distance, detection processing and measurement processing may be repeated and the time when measurement data becomes smaller than the reference distance by a significant difference may be set as the time to start processing.

[0120] In a case where little reflected light is incident on light receiving unit 102 when a surface of the belt conveyor is irradiated with laser beam L1 from displacement sensor 1, based on transition from a state where a certain light receiving amount is obtained to a value for the light receiving amount close to zero, such determination that the time to end processing on a workpiece model has come may be made. In a case where reflected light from the belt conveyor is incident on light receiving unit 102, with a distance from sensor head 10 to the surface of the conveyor being registered as the reference distance, such determination that the time to end processing on a workpiece model has come may be made based on the fact that measurement data has recovered the reference distance.

[0121] In a case where teaching processing is performed while a belt conveyor or the like successively carries a plurality of types of workpiece models, detection processing and measurement processing are repeated as workpiece models are carried, and data to be used for teaching processing (measurement data corresponding to each workpiece model) may be selected from a history of measurement data obtained in such processing. For example, a graph showing variation in measurement data may be displayed on a display unit of such an external device as a computer and the user may individually designate a range corresponding to each workpiece model in the graph with the use of such an input device as a mouse, so that, for each workpiece model, measurement data corresponding to that model can be obtained.

[0122] In a case where a workpiece having a plurality of parts different in reflectance is to be detected, an edge on a downstream side in a path for carrying the workpiece and a boundary position between the parts may be marked with a thin film made of a material higher in reflectance than each part (for example, aluminum), and each time a peak corresponding to the reflectance of the thin film appears in the light receiving amount in light receiving unit 102, determination that a part to be detected has changed may be made and the number of pieces of data of moving average calculation may be found.

[0123] Alternatively, an imaging element for a color image is introduced in light receiving unit 102 and a color of a workpiece to be detected is registered in advance. Then, while detection processing is repeated, based on the fact that a region having a registered color is included in an image among images input from light receiving unit 102, determination that the time to start processing on a workpiece model has come may be made. In a case where an imaging element for a color image is introduced in light receiving unit 102, instead of marking with a thin film described previously, marking with a particular color may be set and that color may be detected.

[0124] Further, with regard to target value RT0 for a response time, not only a user's direct input of a numerical value but also input of a moving speed of a workpiece or a length along a direction in which the workpiece is carried may be accepted and target value RT0 may be calculated from these values. Similarly, in a case where a displacement sensor is installed for the purpose of detecting an amount of displacement of an outer circumferential surface of a disc-shaped or cylindrical substance while the substance is turning, input of a rotation speed or a diameter of the substance may be accepted and target value RT0 for a response time may be found out from these values. It is noted that this type of calculation is not limited to calculation performed by using a sensor but may be performed by an external device.

[0125] After the number of pieces of data of moving average calculation is registered, test measurement of a workpiece model may be conducted based on that registration, and an actual response time or detection data may be displayed such that whether a condition designated by the user is satisfied or not can be checked. In addition, in this case, the

registered number of pieces of data of moving average calculation may be corrected in response to an operation to designate change in displayed response time or accuracy in detection data.

[0126] Displacement sensor 1 configured as above can also have a function to output the number of pieces of data N of moving average calculation derived in teaching processing to an external device or a function to receive input of the number of pieces of data N from an external device and to register the same in memory 111 to the contrary. By doing so, in a case where a common workpiece is to be detected by a plurality of displacement sensors 1, such as a case where displacement sensors 1 are arranged at a plurality of locations on a single belt conveyor, the number of pieces of data N derived by any one sensor 1 can be transferred to another sensor 1 through an external device. According to this method, by subjecting only one of the plurality of displacement sensors 1 to teaching processing, the number of pieces of data N derived in that teaching processing can be registered in all displacement sensors 1, so that the user's efforts in connection with teaching processing can significantly be lessened.

[0127] It is noted that, by allowing communication between sensors, the number of pieces of data N above can also directly be passed between the sensors without through an external device.

[0128] In the teaching processing described so far, the user designates at least one of target value RT0 for a response time and tolerance value D0 for detection error and the number of pieces of data N of moving average calculation suitable for the designated condition is derived, however, it is also possible that, without designation of target value RT0 or tolerance value D0, a workpiece model is installed at a position where it is irradiated with laser beam L1 and detection processing, measurement processing, and the like are performed, so that a value appropriate for the number of pieces of data N of moving average calculation is automatically found out and registered.

[0129] In this case as well, a workpiece model is installed at a position where it is irradiated with laser beam L1, and detection processing and measurement processing are started in response to a start indication operation or an external signal input. In addition, maximum exposure time ST is determined and variation in measurement data V is calculated while processing for adjusting an exposure time is performed based on intensity of every light receiving amount.

[0130] Here, maximum exposure time ST and variation in measurement data V are applied to Expression A and Expression B, respectively. Then, as shown in Fig. 6, a function f_A representing relation between the number of pieces of data N of moving average calculation and response time RT and a function f_B representing relation between the number of pieces of data N of moving average calculation and detection error D can be specified. Therefore, for example, values N_K, RT_K, D_K corresponding to a coordinate at an intersection of a graph of function f_A and a graph of function f_B for N, RT, D are found, N_K is displayed as the number of pieces of data to be registered, and RT_K and D_K are displayed as a response time and detection accuracy respectively in a case where moving average calculation using the number of pieces of data N_K is performed. When the user confirms such display contents and performs a registration operation, a value for N_K is registered in memory 111.

[0131] Alternatively, three numerical values of N_K above, a value (N_K-E) calculated by subtracting a prescribed number E from N_K, and a value (N_K+E) obtained by adding E to N_K are set as registration candidates, N_K is defined as such a setting value that a response time and detection accuracy are in good balance, N_K-E is defined as a setting value in a case where priority is placed on a response time, N_K+E is defined as a setting value in a case where priority is placed on detection accuracy, and then they are each combined with corresponding response time and detection accuracy. Such combinations may be displayed to have the user select any combination.

[0132] In addition, the number of pieces of data does not necessarily have to be displayed, and combinations of a response time and detection accuracy corresponding to each number of pieces of data may be displayed and a selection operation may be accepted. Alternatively, an operation to designate a value higher or lower than a response time or detection accuracy displayed here may be accepted to change display of a response time and detection accuracy, and when resultant display is selected, the number of pieces of data corresponding to that display may be registered.

[0133] Finally, operation processing based on a processing time period for detection processing (a maximum exposure time) or on variation in measurement data is performed to derive the number of pieces of data of moving average calculation in connection with a displacement sensor of a type measuring an amount of displacement based on principles of triangulation has been described so far, however, a displacement sensor for measuring an amount of displacement with other methods being capable of finding the number of pieces of data of moving average calculation by executing a similar teaching mode will also be described.

[0134] For example, in a displacement sensor of a TOF type, a processing time period for detection processing should be adjusted depending on a length of a distance that may be detected. Therefore, for example, by adjusting a processing time period for detection processing in such a state that a lowest part of a workpiece model is detected, the processing time period should be determined and variation in measurement data should be found. Thereafter, the number of pieces of data N of moving average calculation can be found with a method similar to that in each embodiment above, and the number of pieces of data can be registered together with the adjusted processing time period.

[0135] In a displacement sensor of a phase difference rangefinding type or of a PC code rangefinding type, in order to make an amplitude of a wave included in a signal indicating a light receiving amount of reflected light sufficiently great, an exposure time should be adjusted as in a displacement sensor of a triangulation type. In addition, as an exposure

time is longer, the number of waves included in a signal indicating a light receiving amount of reflected light increases, so that more stable measurement processing can be achieved. Therefore, in teaching processing of a displacement sensor of this type, desirably, after an exposure time becomes stable as a result of adjustment processing, detection processing and measurement processing are performed prescribed times and variation in measurement data during that period is found. In this case as well, a maximum exposure time is determined while an exposure time is adjusted, and this maximum exposure time and variation in measurement data can be used to find the number of pieces of data N of moving average calculation and to register the same.

REFERENCE SIGNS LIST

[0136] W workpiece; 1 displacement sensor; 101 light projecting unit; 102 light receiving unit; 103 light emitting element; 104 light projection control circuit; 105 imaging element; 106 signal processing circuit; 107 A/D conversion circuit; 110 CPU; 111 memory; 121 display unit; 122 operation unit; and 123 input/output interface.

Claims

1. A displacement sensor (1) configured for repeatedly executing, in a normal operation mode, a detection process of projecting light to an object (W) and receiving the light reflected from the object (W), a measurement process of measuring an amount of displacement of the object (W) based on the result of reception of said reflected light, and a moving average calculation of data of said measurement, for outputting detection data based on an average value obtained by the moving average calculation, comprising:

input means (122) configured for inputting either one of a numerical value representing a target value of a response time of said displacement sensor (1), or a numerical value representing an error tolerance value of detection data, or both; and
teaching mode executing means (110) for executing a teaching mode in which the number of pieces of data of said moving average calculation is determined and registered, said teaching mode executing means (110) including:

measurement data variation calculating means (110) for executing said detection process and said measurement process, each for a plurality of times, on an actual model of the object to be detected, and executing a process of calculating variation of measurement data obtained by said measurement process,
data number derivation means (110) for calculating the number of pieces of data of moving average calculation at which the target value of the response time and/or the error tolerance value of the detection data input into the input means (122) are met, by an operation using results of processing by said measurement data variation calculating means (110), and
registration processing means (110) for registering the calculated number of pieces of data of said moving average calculation; and

a memory (111) in which the number of pieces of data of said moving average calculation can be registered by the registration processing means (110) for use in the normal operation mode.

2. The displacement sensor (1) according to claim 1, wherein
said data number derivation means (110) is configured to execute an operation using at least one of a first operational expression representing a relation among processing time of said detection process, the number of pieces of data of the moving average calculation and the response time, and a second operational expression representing a relation among the variation of measurement data, the number of pieces of data of the moving average calculation and the error of detection data.

3. The displacement sensor (1) according to claim 2, wherein
the data number derivation means (110) is configured such that, when both said parameters representing said target value of the response time and the error tolerance value of detection data are input to the input means (122), said data number derivation means (110) selects either one of the parameters with priority, executes a first operation of calculating the number of pieces of data of moving average calculation by applying the value input for the parameter and the result of processing by said measurement data variation calculating means (110) to the operational expression corresponding to the selected parameter, and thereafter executes a second operation by applying the number of pieces of data of moving average calculated by said first operation and the result of processing by said meas-

urement data variation calculating means (110) to the operational expression corresponding to the non-selected parameter, to calculate the value of the parameter, and
said registration processing means (110) is configured to determine whether or not the value of said non-selected parameter calculated by said second operation matches the value input to said input means (122), and when it is determined to be matching, registers the number of pieces of data of moving average calculated by said first operation with said memory (111).

4. The displacement sensor (1) according to claim 3, further comprising output means for outputting, when it is determined by said registration processing means (110) that the value of said non-selected parameter calculated by said second operation does not match the value input to said input means (122), the value of said parameter calculated by the second operation for display.

5. The displacement sensor (1) according to claim 1, further comprising signal input means for inputting a signal instructing start of processing in said teaching mode, wherein
said measurement data variation calculating means (110) is configured to operate in response to an input of the signal.

6. The displacement sensor (1) according to claim 5, wherein
the data number derivation means (110) and the registration processing means (110) are configured to operate together with said measurement data variation calculating means (110), every time said signal instructing start of processing is input, and
the registration processing means (110) is configured to determine, in response to the input of the signal for the second time and onwards, an optimal value of the number of pieces of data of moving average, using the number of pieces of data derived from processing by said measurement data variation calculating means (110) and said data number derivation means (110) in response to the input, and the number of pieces of data registered with said memory (111) in response to the signal input last time.

7. The displacement sensor (1) according to claim 5, further comprising second signal input means for inputting a signal instructing end of processing in said teaching mode, wherein
said measurement data variation calculating means (110) and said data number derivation means (110) are configured to operate every time said signal instructing start of processing is input, and said registration processing means (110) is configured to operate in response to an input of said signal instructing end of processing, and
the registration processing means (110) is configured such that, when said signal instructing start of processing is input a plurality of times before said signal instructing end of processing is input, said registration processing means (110) determines an optimal value of the number of pieces of data of moving average, using the number of pieces of data of each moving average derived by the data number derivation means (110) in response to every input of said signal.

8. The displacement sensor (1) according to claim 5, further comprising second signal input means for inputting a signal instructing end of processing in said teaching mode, wherein
said measurement data variation calculating means (110) and said data number derivation means (110) are configured to operate in response to an input of said signal instructing start of processing, and said registration processing means (110) operates in response to an input of said signal instructing end of processing,
said measurement data variation calculating means (110) and said data number derivation means (110) are capable of executing processes a plurality of times from the input of said signal instructing start of processing until the input of said signal instructing end of processing, and
the registration processing means (110) is configured such that, when a plurality of numbers of data of moving average are derived by said data number derivation means (110) before said signal instructing end of processing is input, said registration processing means (110) determines an optimal value of the number of pieces of data of moving average, using these numbers of data.

9. The displacement sensor (1) according to claim 7 or 8, further comprising an operation unit for generating said signal instructing start of processing and said signal instructing end of processing.

Patentansprüche

1. Verschiebungssensor (1), der dazu eingerichtet ist, in einem Normalbetriebsmodus wiederholt Folgendes auszuführen: einen Erkennungsprozesses, bei welchem Licht auf ein Objekt (W) projiziert und das von dem Objekt (W)

reflektierte Licht empfangen wird, einen Messprozess, bei welchem ein Verschiebungsbetrag des Objekts (W) basierend auf dem Ergebnis des Empfangens des reflektierten Lichts gemessen wird, und eine Berechnung eines gleitenden Mittels von Daten der Messung, um basierend auf einem durch die Berechnung eines gleitenden Mittels erlangten Mittelwerts Erkennungsdaten auszugeben, umfassend:

ein Eingabemittel (122), das zum Eingeben entweder eines numerischen Werts, der einen Sollwert einer Antwortzeit des Verschiebungssensors (1) repräsentiert, oder eines numerischen Werts, der einen Fehlertoleranzwert von Erkennungsdaten repräsentiert, oder von beiden eingerichtet ist; und
ein Lernmodus-Ausführmittel (110) zum Ausführen eines Lernmodus, bei welchem die Anzahl von Datenelementen der Berechnung eines gleitenden Mittels bestimmt und registriert wird, wobei das Lernmodus-Ausführmittel (110) Folgendes aufweist:

ein Messdatenvariations-Berechnungsmittel (110) zum jeweils mehrmaligen Ausführen des Erkennungsprozesses und des Messprozesses an einem tatsächlichen Modell des zu erkennen Objekts, und zum Ausführen eines Prozesses, bei dem eine Variation der von dem Messprozess erlangten Messdaten berechnet wird,
ein Datenanzahl-Ableitmittel (110) zum Berechnen der Anzahl von Datenelementen der Berechnung eines gleitenden Mittels, bei welcher der in das Eingabemittel (122) eingegebene Sollwert der Antwortzeit und/oder Fehlertoleranzwert der Erkennungsdaten eingehalten wird, durch eine Operation, bei welcher Ergebnisse der Verarbeitung durch das Messdatenvariations-Berechnungsmittel (110), und
ein Registrierungs-Verarbeitungsmittel (110) zum Registrieren der berechneten Anzahl von Datenelementen der Berechnung eines gleitenden Mittels; und

einen Arbeitsspeicher (111), in welchem die Anzahl der Datenelemente der Berechnung eines gleitenden Mittels von dem Registrierungsverarbeitungsmittel (110) zur Verwendung in dem Normalbetriebsmodus registriert werden kann.

2. Verschiebungssensor (1) nach Anspruch 1, wobei
das Datenanzahl-Ableitmittel (110) dazu eingerichtet ist, eine Operation unter Verwendung von Folgendem auszuführen: eines ersten operationalen Ausdrucks, welcher eine Beziehung zwischen einer Verarbeitungszeit des Erkennungsprozesses, der Anzahl der Datenelemente der Berechnung eines gleitenden Mittels und der Antwortzahl repräsentiert, und/oder eines zweiten operationalen Ausdrucks, welcher eine Beziehung zwischen der Variation der Messdaten, der Anzahl der Datenelemente der Berechnung eines gleitenden Mittels und dem Fehler der Erkennungsdaten repräsentiert.

3. Verschiebungssensor (1) nach Anspruch 2, wobei
das Datenanzahl-Ableitmittel (110) derart angerichtet ist, dass, wenn beide der Parameter, die den Sollwert der Antwortzeit und den Fehlertoleranzwert der Erkennungsdaten repräsentieren, in das Eingabemittel (122) eingegeben werden, das Datenanzahl-Ableitmittel (110) genau einen der Parameter mit Priorität auswählt, eine erste Operation, bei welcher die Anzahl der Datenelemente der Berechnung eines gleitenden Mittels berechnet wird, dadurch ausführt, dass er den für den Parameter eingegebenen Wert und das Ergebnis der Verarbeitung durch das Messdatenvariations-Berechnungsmittel (110) auf den operationalen Ausdruck anwendet, welcher dem gewählten Parameter entspricht, und danach eine zweite Operation ausführt, bei welcher er die mit der ersten Operation berechnete Anzahl der Datenelemente der Berechnung eines gleitenden Mittels und das Ergebnis der Verarbeitung durch das Messdatenvariations-Berechnungsmittel (110) auf den dem nicht gewählten Parameter entsprechenden operationalen Ausdruck anwendet, um den Wert des Parameters zu berechnen, und
das Registrierungs-Verarbeitungsmittel (110) dazu eingerichtet ist, zu bestimmen, ob der von dem zweiten Vorgang berechnete Wert des nicht gewählten Parameters dem in das Eingabemittel (122) eingegebenen Wert entspricht, und wenn bestimmt wird, dass eine Entsprechung vorliegt, die Anzahl der Datenelemente des mit der ersten Operation berechneten gleitenden Mittels in dem Arbeitsspeicher (111) zu registrieren.

4. Verschiebungssensor (1) nach Anspruch 3, ferner umfassend Ausgabemittel, welche dazu dienen, wenn durch das Registrierungs-Verarbeitungsmittel (110) bestimmt wird, dass der mit der zweiten Operation berechnete Wert des nicht gewählten Parameters nicht mit dem in das Eingabemittel (122) eingegebenen Wert übereinstimmt, den Wert des mit der zweiten Operation berechneten Werts des Parameters zur Anzeige auszugeben.

5. Verschiebungssensor (1) nach Anspruch 1, ferner umfassend ein Signaleingabemittel zum Eingeben eines Signals, welches einen Beginn einer Verarbeitung in dem Lernmodus anweist, wobei

das Messdatenvariations-Berechnungsmittel (110) dazu eingerichtet ist, in Reaktion auf eine Eingabe des Signals zu arbeiten.

6. Verschiebungssensor (1) nach Anspruch 5, wobei
das Datenanzahl-Ableitmittel (110) und das Registrierungs-Verarbeitungsmittel (110) dazu eingerichtet sind, jedes Mal, wenn das Signal, das den Beginn der Bearbeitung anweist, eingegeben wird, zusammen mit dem Messdatenvariations-Berechnungsmittel (110) zu arbeiten, und
das Registrierungs-Verarbeitungsmittel (110) dazu eingerichtet ist, in Reaktion auf das zweite und jedes weitere Eingeben des Signals einen optimalen Wert der Anzahl Datenelemente des gleitenden Mittels unter Verwendung von Folgendem zu bestimmen: der Anzahl von Datenelementen, die von der Verarbeitung durch das Messdatenvariations-Berechnungsmittel (110) und das Datenanzahl-Ableitmittel (110) als Reaktion auf die Eingabe abgeleitet wurde, sowie der Anzahl von Datenelementen, die in Reaktion auf das beim vorherigen Mal eingegebene Signal in dem Arbeitsspeicher (111) registriert wurde.

7. Verschiebungssensor (1) nach Anspruch 5, ferner umfassend ein zweites Signaleingabemittel zum Eingeben eines Signals, welches ein Ende der Verarbeitung in dem Lernmodus anweist, wobei
des Messdatenvariations-Berechnungsmittel (110) und das Datenanzahl-Ableitmittel (110) dazu eingerichtet sind, bei jedem Eingaben des Signals, das den Beginn der Verarbeitung anweist, zu arbeiten, und das Registrierungs-Verarbeitungsmittel (110) dazu eingerichtet ist, in Reaktion auf eine Eingabe des Signals, das das Ende der Verarbeitung anweist, zu arbeiten, und
das Registrierungs-Verarbeitungsmittel (110) derart eingerichtet ist, dass, wenn das Signal, welches den Beginn der Verarbeitung anweist, mehrmals eingegeben wird, bevor das Signal, welches das Ende der Verarbeitung anweist, eingegeben wird, das Registrierungs-Verarbeitungsmittel (110) einen optimalen Wert der Anzahl von Datenelementen des gleitenden Mittels unter Verwendung der in Reaktion auf jede Eingabe des Signals durch das Datenanzahl-Ableitmittel (110) abgeleiteten Anzahl von Datenelementen eines jeweiligen gleitenden Mittels bestimmt.

8. Verschiebungssensor (1) nach Anspruch 5, ferner umfassend ein zweites Signaleingabemittel zum Eingeben eines Signals, welches ein Ende der Verarbeitung in dem Lernmodus anweist, wobei
das Messdatenvariations-Berechnungsmittel (110) und das Datenanzahl-Ableitmittel (110) dazu eingerichtet sind, in Reaktion auf eine Eingabe des Signals, welches den Start der Verarbeitung anweist, zu arbeiten, und das Registrierungs-Verarbeitungsmittel (110) in Reaktion auf eine Eingabe des Signals arbeitet, welches das Ende der Verarbeitung anweist,
das Messdatenvariations-Berechnungsmittel (110) und das Datenanzahl-Ableitmittel (110) dazu in der Lage sind, von der Eingabe des Signals, welches den Beginn der Verarbeitung anweist, bis zu der Eingabe des Signals, welches das Ende der Verarbeitung anweist, Prozesse mehrmals auszuführen, und
das Registrierungs-Verarbeitungsmittel (110) derart eingerichtet ist, dass, wenn von dem Datenanzahl-Ableitmittel (110) mehrere Anzahlen Daten des gleitenden Mittels abgeleitet werden, bevor das Signal, welches das Ende der Verarbeitung anweist, eingegeben wird, das Registrierungs-Verarbeitungsmittel (110) einen optimalen Wert der Anzahl von Datenelementen des gleitenden Mittels unter Verwendung dieser Anzahlen von Daten bestimmt.

9. Verschiebungssensor (1) nach Anspruch 7 oder 8, ferner umfassend eine Bedieneinheit zum Generieren des Signals, welches den Beginn der Verarbeitung anweist, und des Signals, welches das Ende der Verarbeitung anweist.

Revendications

1. Capteur de déplacement (1) configuré pour exécuter de manière répétée, dans un mode de fonctionnement normal, un processus de détection consistant à projeter une lumière vers un objet (W) et à recevoir la lumière réfléchie par l'objet (W), un processus de mesure consistant à mesurer une quantité de déplacement de l'objet (W) sur la base du résultat de la réception de ladite lumière réfléchie, et un calcul de moyenne mobile de données de ladite mesure, pour délivrer des données de détection sur la base d'une valeur moyenne obtenue par le calcul de moyenne mobile, comprenant :

un moyen d'entrée (122) configuré pour entrer l'une ou l'autre d'une valeur numérique représentant une valeur cible d'un temps de réponse dudit capteur de déplacement (1), ou d'une valeur numérique représentant une valeur de tolérance d'erreur de données de détection, ou les deux ; et
un moyen d'exécution de mode d'apprentissage (110) pour exécuter un mode d'apprentissage dans lequel le nombre d'éléments de données dudit calcul de moyenne mobile est déterminé et enregistré, ledit moyen d'exé-

cution de mode d'apprentissage comprenant :

un moyen de calcul de variation de données de mesure (110) pour exécuter ledit processus de détection et ledit processus de mesure, chacun une pluralité de fois, sur un modèle réel de l'objet à détecter, et exécuter un processus de calcul de variation des données de mesure obtenues par ledit processus de mesure,
un moyen de dérivation de nombre de données (110) pour calculer le nombre d'éléments de données de calcul de moyenne mobile auquel la valeur cible du temps de réponse et/ou la valeur de tolérance d'erreur des données de détection entrées dans le moyen d'entrée (122) sont satisfaites, par une opération utilisant des résultats de traitement par ledit moyen de calcul de variation de données de mesure (110), et
un moyen de traitement d'enregistrement (110) pour enregistrer le nombre calculé d'éléments de données dudit calcul de moyenne mobile ; et
une mémoire (111) dans laquelle le nombre d'éléments de données dudit calcul de moyenne mobile peut être enregistré par le moyen de traitement d'enregistrement (110) destiné à être utilisé dans le mode de fonctionnement normal.

2. Capteur de déplacement (1) selon la revendication 1, dans lequel
ledit moyen de dérivation de nombre de données (110) est configuré pour exécuter une opération en utilisant au moins l'un d'une première expression opérationnelle représentant une relation entre le temps de traitement dudit processus de détection, le nombre d'éléments de données du calcul de moyenne mobile et le temps de réponse, et d'une seconde expression opérationnelle représentant une relation entre la variation de données de mesure, le nombre d'éléments de données du calcul de moyenne mobile et l'erreur de données de détection.

3. Capteur de déplacement (1) selon la revendication 2, dans lequel
le moyen de dérivation de nombre de données (110) est configuré de sorte que, lorsque lesdits deux paramètres représentant ladite valeur cible du temps de réponse et la valeur de tolérance d'erreur de données de détection sont entrés dans le moyen d'entrée (122), ledit moyen de dérivation de nombre de données (110) sélectionne l'un ou l'autre des paramètres avec priorité, exécute une première opération de calcul du nombre d'éléments de données de calcul de moyenne mobile en appliquant la valeur entrée pour le paramètre et le résultat de traitement par ledit moyen de calcul de variation de données de mesure (110) à l'expression opérationnelle correspondant au paramètre sélectionné, et exécute ensuite une seconde opération en appliquant le nombre d'éléments de données de moyenne mobile calculé par ladite première opération et le résultat de traitement par ledit moyen de calcul de variation de données de mesure (110) à l'expression opérationnelle correspondant au paramètre non sélectionné, pour calculer la valeur du paramètre, et
ledit moyen de traitement d'enregistrement (110) est configuré pour déterminer si oui ou non la valeur dudit paramètre non sélectionné calculée par ladite seconde opération correspond à la valeur entrée dans ledit moyen d'entrée (122), et, s'il est déterminé qu'elle correspond, enregistre le nombre d'éléments de données de moyenne mobile calculé par ladite première opération avec ladite mémoire (111).

4. Capteur de déplacement (1) selon la revendication 3, comprenant en outre un moyen de sortie pour délivrer, lorsqu'il est déterminé par ledit moyen de traitement d'enregistrement (110) que la valeur dudit paramètre non sélectionné calculée par ladite seconde opération ne correspond pas à la valeur entrée dans ledit moyen d'entrée (122), la valeur dudit paramètre calculée par la seconde opération pour être affichée.

5. Capteur de déplacement (1) selon la revendication 1, comprenant en outre un moyen d'entrée de signal pour entrer un signal ordonnant le début du traitement dans ledit mode d'apprentissage, dans lequel
ledit moyen de calcul de variation de données de mesure (110) est configuré pour fonctionner en réponse à une entrée du signal.

6. Capteur de déplacement (1) selon la revendication 5, dans lequel
le moyen de dérivation de nombre de données (110) et le moyen de traitement d'enregistrement (110) sont configurés pour fonctionner avec conjointement avec ledit moyen de calcul de variation de données de mesure (110), chaque fois que ledit signal ordonnant le début du traitement est entré, et
le moyen de traitement d'enregistrement (110) est configuré pour déterminer, en réponse à l'entrée du signal pour la seconde fois et par la suite, une valeur optimale du nombre d'éléments de données de moyenne mobile, en utilisant le nombre d'éléments de données dérivé du traitement par ledit moyen de calcul de variation de données de mesure (110) et ledit moyen de dérivation de nombres de données (110) en réponse à l'entrée, et le nombre d'éléments de données enregistré avec ladite mémoire (111) en réponse au signal entré en dernier.

7. Capteur de déplacement (1) selon la revendication 5, comprenant en outre un second moyen d'entrée de signal pour entrer un signal ordonnant la fin du traitement dans ledit mode d'apprentissage, dans lequel
ledit moyen de calcul de variation de données de mesure (110) et ledit moyen de dérivation de nombres de données (110) sont configurés pour fonctionner chaque fois que ledit signal ordonnant le début du traitement est entré, et ledit moyen de traitement d'enregistrement (110) est configuré pour fonctionner en réponse à une entrée dudit signal ordonnant la fin du traitement, et
le moyen de traitement d'enregistrement (110) est configuré de sorte que, lorsque ledit signal ordonnant le début du traitement est entré une pluralité de fois avant que ledit signal ordonnant la fin du traitement soit entré, ledit moyen de traitement d'enregistrement (110) détermine une valeur optimale du nombre d'éléments de données de moyenne mobile, en utilisant le nombre d'éléments de données de chaque moyenne mobile dérivé par le moyen de dérivation de nombre de données (110) en réponse à chaque entrée dudit signal.

8. Capteur de déplacement (1) selon la revendication 5, comprenant en outre un second moyen d'entrée de signal pour entrer un signal ordonnant la fin du traitement dans ledit mode d'apprentissage, dans lequel
ledit moyen de calcul de variation de données de mesure (110) et ledit moyen de dérivation de nombres de données (110) sont configurés pour fonctionner en réponse à une entrée dudit signal ordonnant le début du traitement, et ledit moyen de traitement d'enregistrement (110) fonctionnent en réponse à une entrée dudit signal ordonnant la fin du traitement,
ledit moyen de calcul de variation de données de mesure (110) et ledit moyen de dérivation de nombre de données (110) sont capables d'exécuter des processus une pluralité de fois à partir de l'entrée dudit signal ordonnant le début du traitement jusqu'à l'entrée dudit signal ordonnant la fin du traitement,
le moyen de traitement d'enregistrement (110) est configuré de sorte que, lorsqu'une pluralité de nombres de données de moyenne mobile sont dérivés par ledit moyen de dérivation de nombre de données (110) avant que ledit signal ordonnant la fin du traitement d'instruction soit entré, ledit moyen de traitement d'enregistrement (110) détermine une valeur optimale du nombre d'éléments de données de moyenne mobile en utilisant ces nombres de données.

9. Capteur de déplacement (1) selon la revendication 7 ou 8, comprenant en outre une unité d'opération pour générer ledit signal ordonnant le début du traitement et ledit signal ordonnant la fin du traitement.

FIG.1

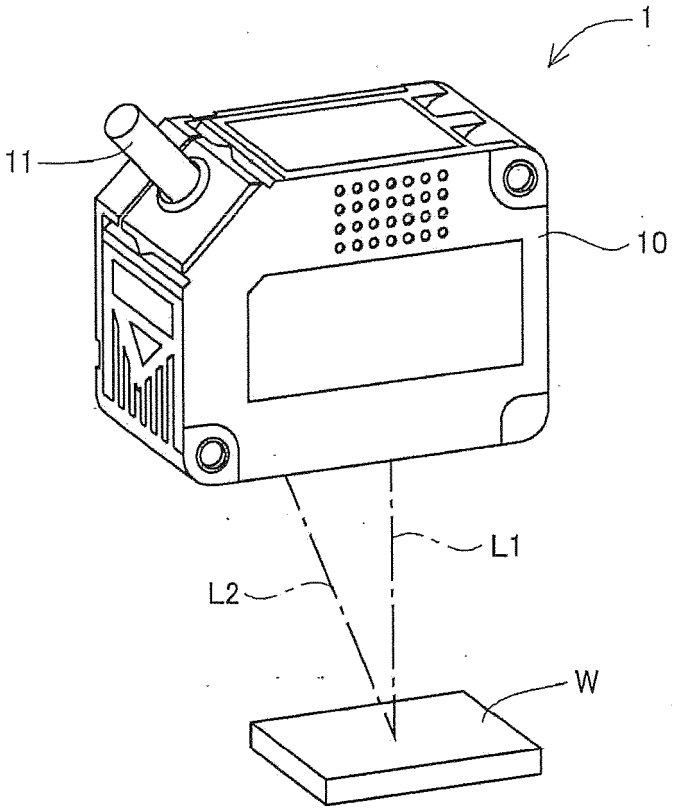


FIG.2

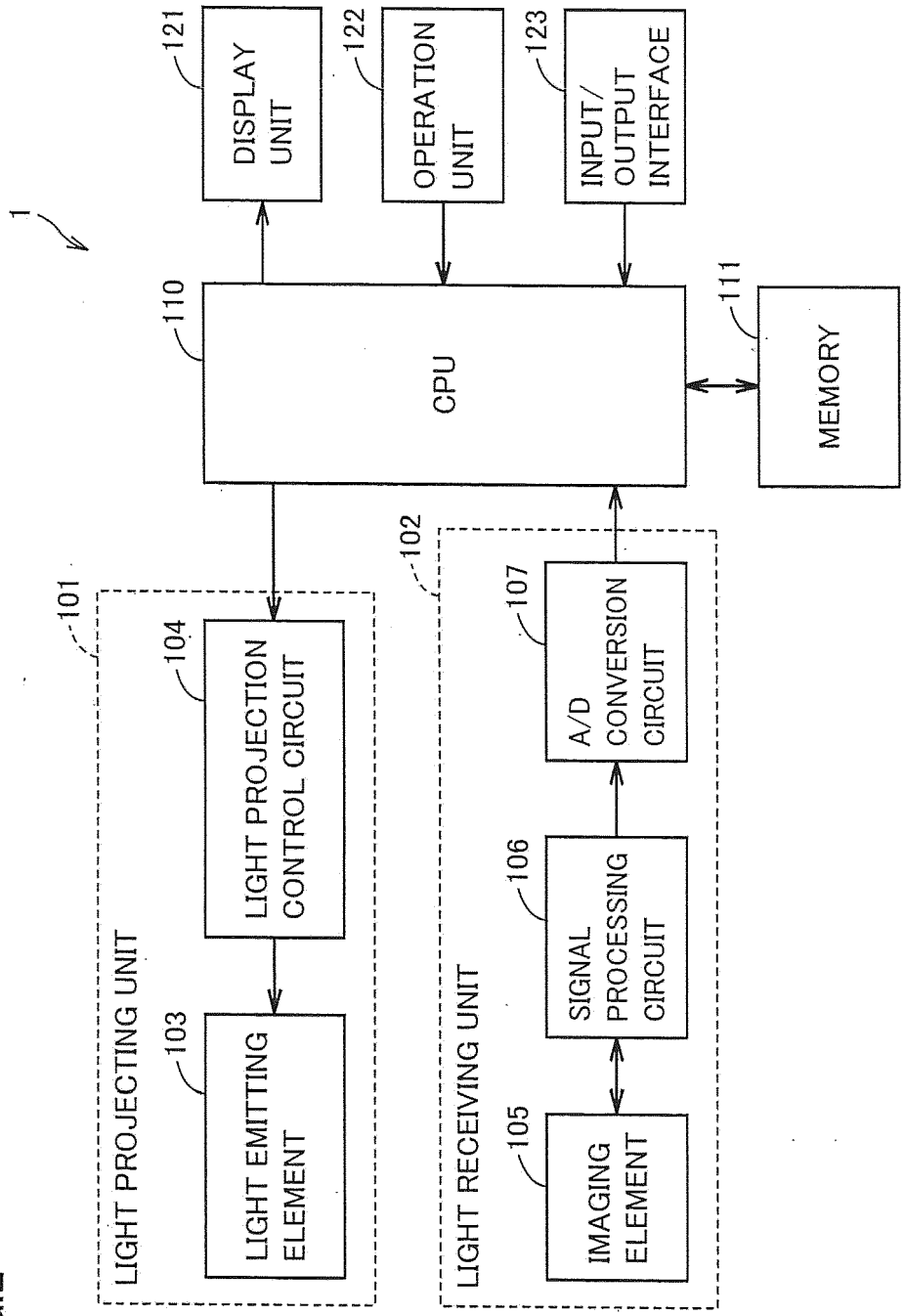

1
121
DISPLAY UNIT
122
OPERATION UNIT
123
INPUT/ OUTPUT INTERFACE
110
CPU
111
MEMORY
101
LIGHT PROJECTING UNIT
104
LIGHT PROJECTION CONTROL CIRCUIT
103
LIGHT EMITTING ELEMENT
102
LIGHT RECEIVING UNIT
107
A/D CONVERSION CIRCUIT
106
SIGNAL PROCESSING CIRCUIT
105
IMAGING ELEMENT

FIG.3

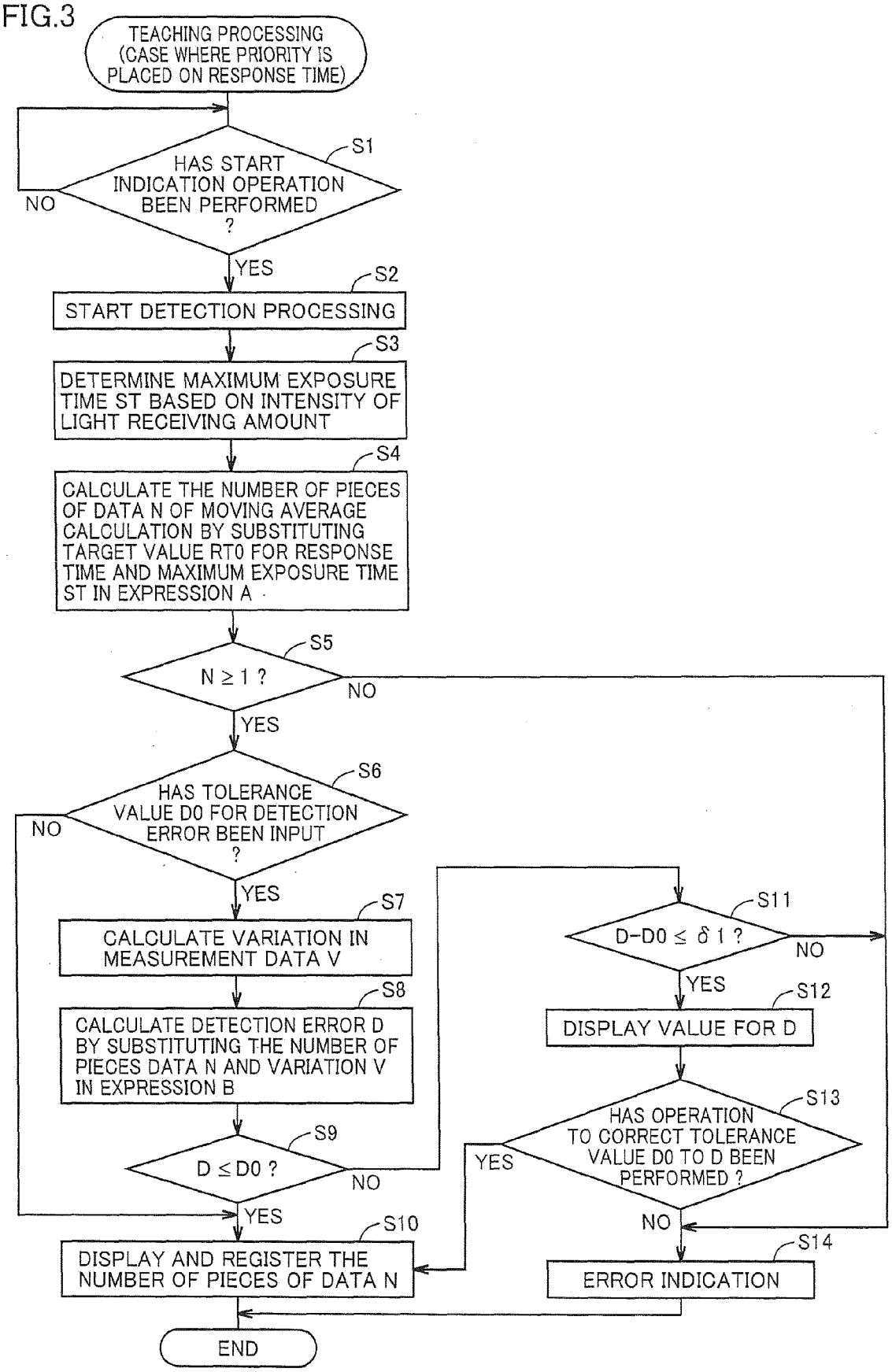

TEACHING PROCESSING (CASE WHERE PRIORITY IS PLACED ON RESPONSE TIME)
S1
HAS START INDICATION OPERATION BEEN PERFORMED ?
NO
YES
S2
START DETECTION PROCESSING
S3
DETERMINE MAXIMUM EXPOSURE TIME ST BASED ON INTENSITY OF LIGHT RECEIVING AMOUNT
S4
CALCULATE THE NUMBER OF PIECES OF DATA N OF MOVING AVERAGE CALCULATION BY SUBSTITUTING TARGET VALUE RT0 FOR RESPONSE TIME AND MAXIMUM EXPOSURE TIME ST IN EXPRESSION A
S5
N ≥ 1 ?
NO
YES
S6
HAS TOLERANCE VALUE D0 FOR DETECTION ERROR BEEN INPUT ?
NO
YES
S7
CALCULATE VARIATION IN MEASUREMENT DATA V
S8
CALCULATE DETECTION ERROR D BY SUBSTITUTING THE NUMBER OF PIECES DATA N AND VARIATION V IN EXPRESSION B
S9
D ≤ D0 ?
NO
YES
S10
DISPLAY AND REGISTER THE NUMBER OF PIECES OF DATA N
S11
D-D0 ≤ δ 1 ?
NO
YES
S12
DISPLAY VALUE FOR D
S13
HAS OPERATION TO CORRECT TOLERANCE VALUE D0 TO D BEEN PERFORMED ?
YES
NO
S14
ERROR INDICATION
END

FIG.4

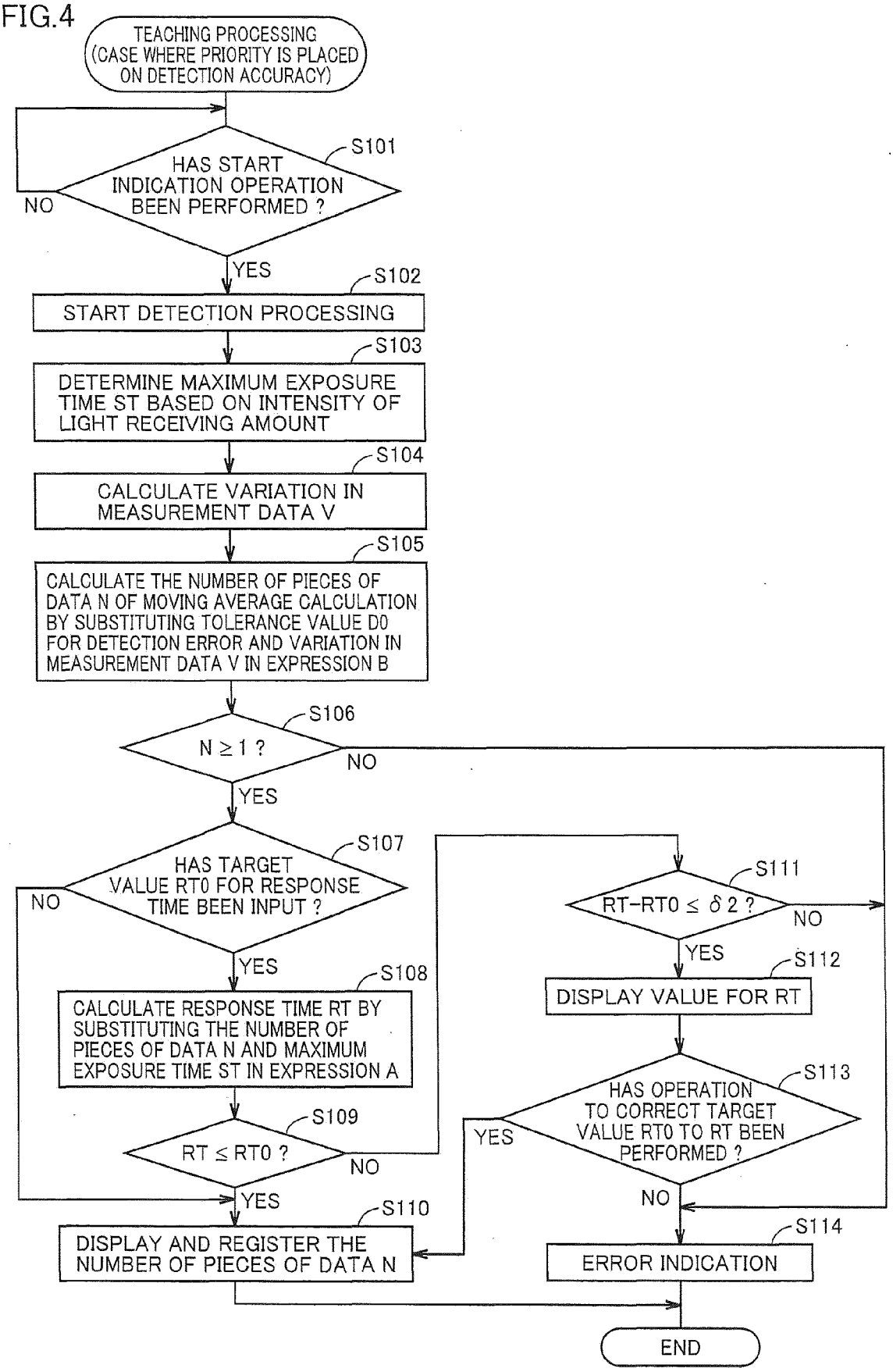

TEACHING PROCESSING (CASE WHERE PRIORITY IS PLACED ON DETECTION ACCURACY)
S101
HAS START INDICATION OPERATION BEEN PERFORMED ?
NO
YES
S102
START DETECTION PROCESSING
S103
DETERMINE MAXIMUM EXPOSURE TIME ST BASED ON INTENSITY OF LIGHT RECEIVING AMOUNT
S104
CALCULATE VARIATION IN MEASUREMENT DATA V
S105
CALCULATE THE NUMBER OF PIECES OF DATA N OF MOVING AVERAGE CALCULATION BY SUBSTITUTING TOLERANCE VALUE D0 FOR DETECTION ERROR AND VARIATION IN MEASUREMENT DATA V IN EXPRESSION B
S106
N ≥ 1 ?
NO
YES
S107
HAS TARGET VALUE RT0 FOR RESPONSE TIME BEEN INPUT ?
NO
YES
S108
CALCULATE RESPONSE TIME RT BY SUBSTITUTING THE NUMBER OF PIECES OF DATA N AND MAXIMUM EXPOSURE TIME ST IN EXPRESSION A
S109
RT ≤ RT0 ?
NO
YES
S110
DISPLAY AND REGISTER THE NUMBER OF PIECES OF DATA N
S111
RT-RT0 ≤ δ2 ?
NO
YES
S112
DISPLAY VALUE FOR RT
S113
HAS OPERATION TO CORRECT TARGET VALUE RT0 TO RT BEEN PERFORMED ?
YES
NO
S114
ERROR INDICATION
END

FIG.5

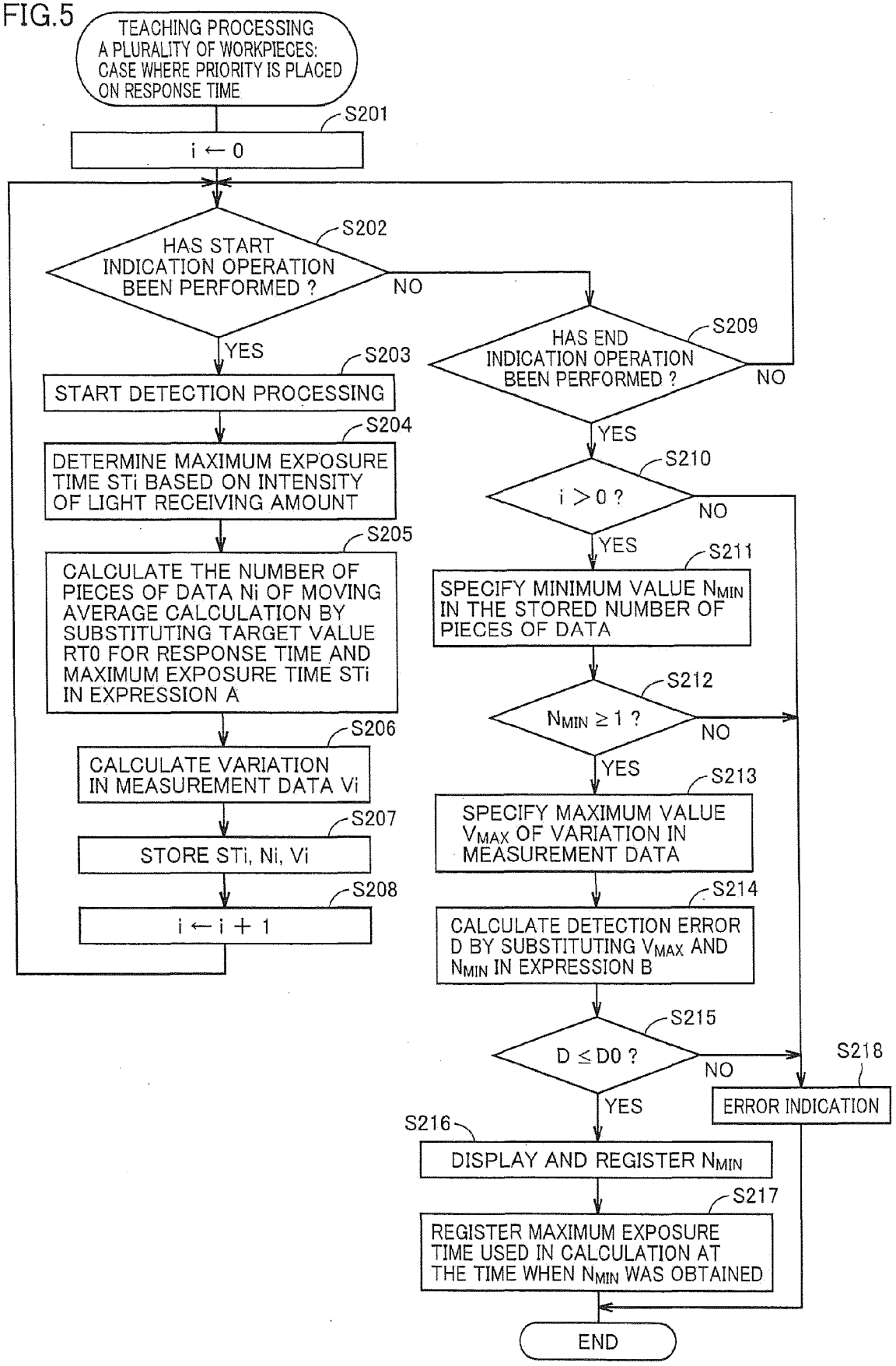
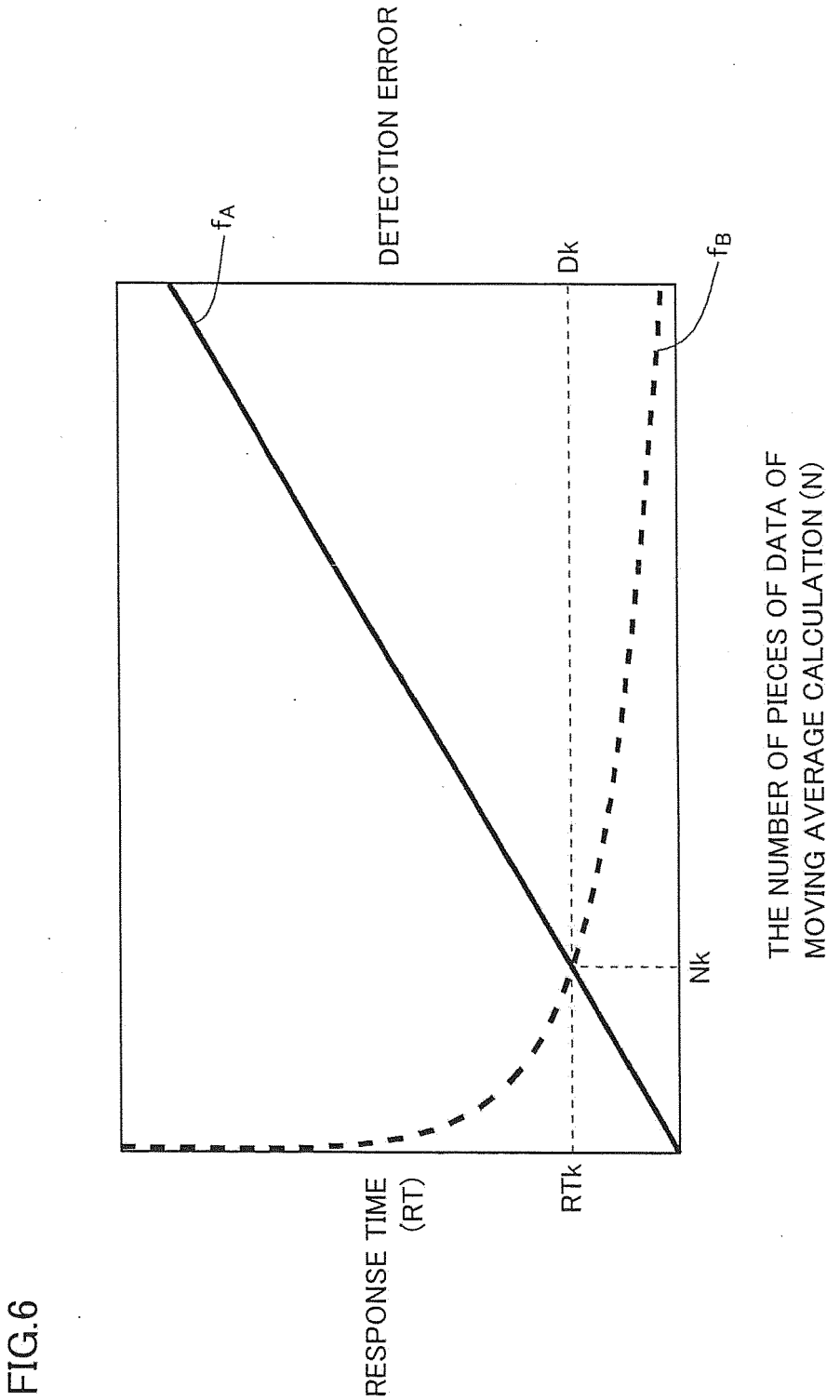

TEACHING PROCESSING A PLURALITY OF WORKPIECES: CASE WHERE PRIORITY IS PLACED ON RESPONSE TIME
S201
i ← 0
S202
HAS START INDICATION OPERATION BEEN PERFORMED ?
NO
YES
S203
START DETECTION PROCESSING
S204
DETERMINE MAXIMUM EXPOSURE TIME STi BASED ON INTENSITY OF LIGHT RECEIVING AMOUNT
S205
CALCULATE THE NUMBER OF PIECES OF DATA Ni OF MOVING AVERAGE CALCULATION BY SUBSTITUTING TARGET VALUE RT0 FOR RESPONSE TIME AND MAXIMUM EXPOSURE TIME STi IN EXPRESSION A
S206
CALCULATE VARIATION IN MEASUREMENT DATA Vi
S207
STORE STi, Ni, Vi
S208
i ← i + 1
S209
HAS END INDICATION OPERATION BEEN PERFORMED ?
NO
YES
S210
i > 0 ?
NO
YES
S211
SPECIFY MINIMUM VALUE NMIN IN THE STORED NUMBER OF PIECES OF DATA
S212
NMIN ≥ 1 ?
NO
YES
S213
SPECIFY MAXIMUM VALUE VMAX OF VARIATION IN MEASUREMENT DATA
S214
CALCULATE DETECTION ERROR D BY SUBSTITUTING VMAX AND NMIN IN EXPRESSION B
S215
D ≤ D0 ?
NO
YES
S218
ERROR INDICATION
S216
DISPLAY AND REGISTER NMIN
S217
REGISTER MAXIMUM EXPOSURE TIME USED IN CALCULATION AT THE TIME WHEN NMIN WAS OBTAINED
END

FIG.6


DETECTION ERROR
f_A
f_B
Dk
Nk
RTk
RESPONSE TIME (RT)
THE NUMBER OF PIECES OF DATA OF MOVING AVERAGE CALCULATION (N)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 3409117 B **[0008]**
- JP 2008058195 A **[0008]**

Non-patent literature cited in the description

- **KAZUMASA TAKADA.** Improvement in Signal-to-Noise Ratio of Rayleigh Backscattering Measurement Using Optical Low Coherence Reflectometry. *Journal of Lightwave Technology,* ISSN 0733-8724 **[0007]**