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(54) **POSITION DETECTING APPARATUS AND COMPUTER-READABLE RECORDING MEDIUM**

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G06T 1/60 (2006.01)

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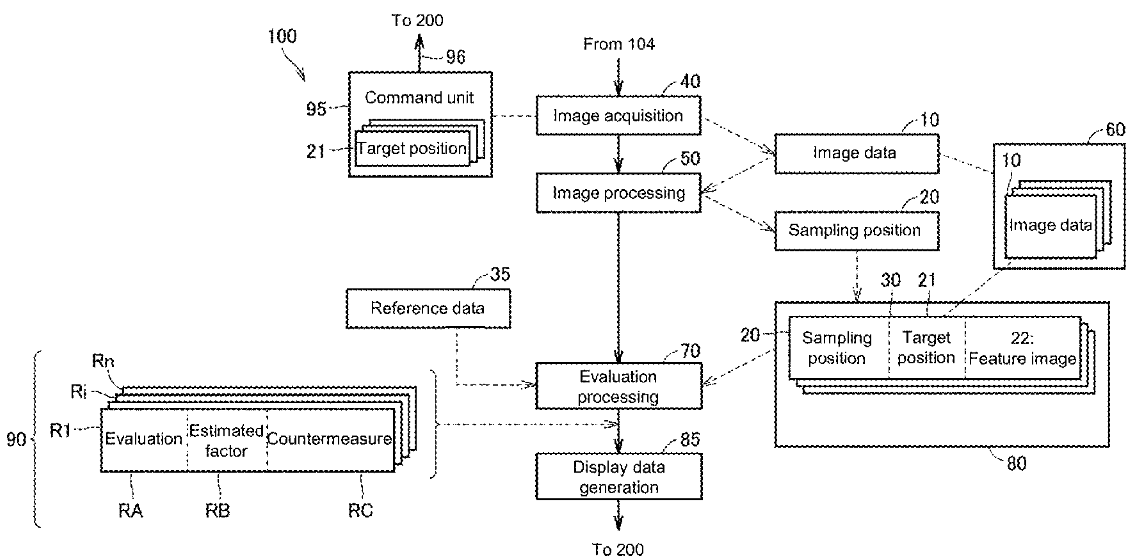
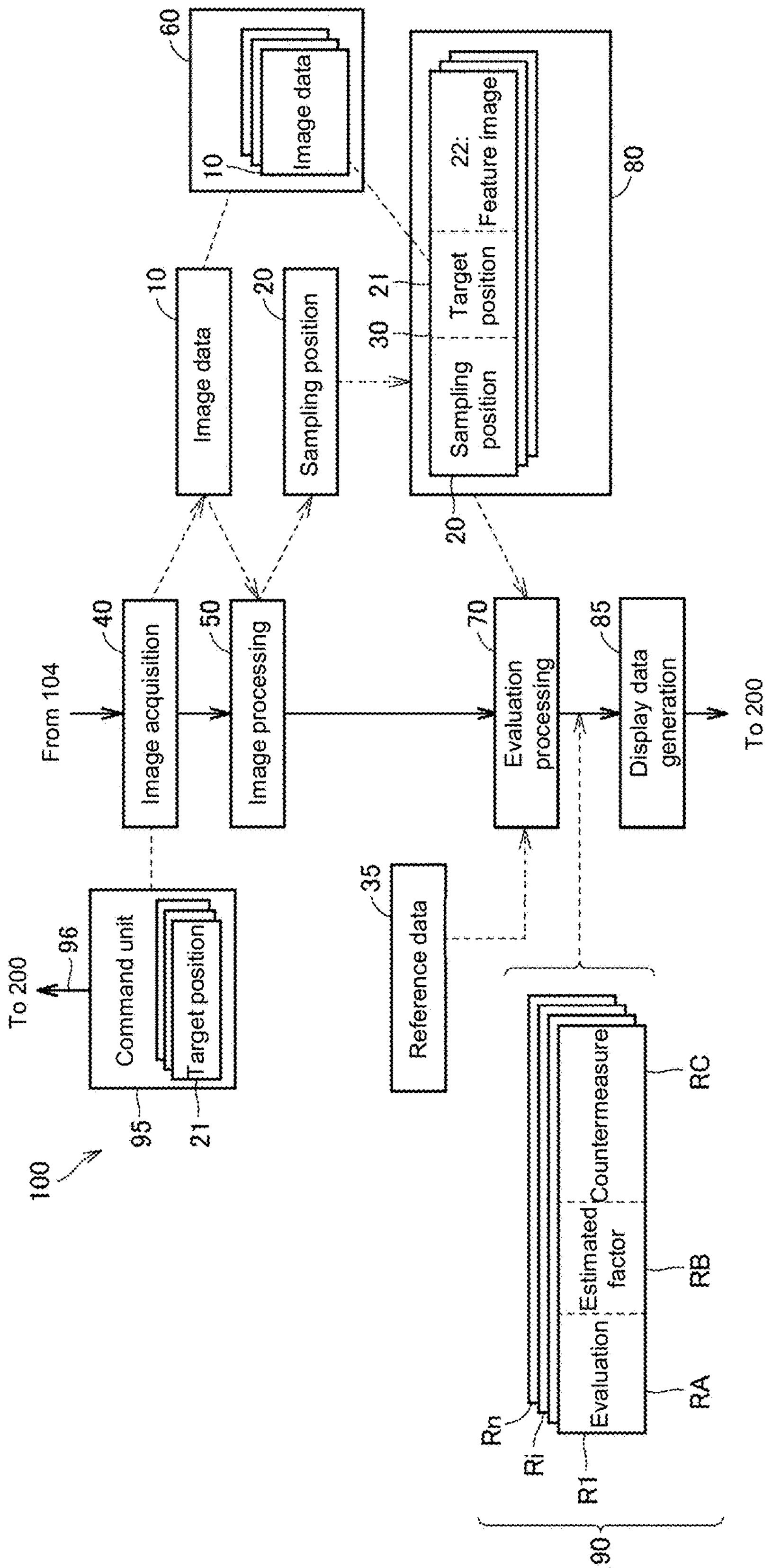
CPC . ***G06T 7/70*** (2017.01); ***G06T 1/60*** (2013.01)

(57) **ABSTRACT**

Provided is an environment for providing information for supporting adjustment of the respective parts for positioning. A position detecting apparatus includes: an image processing unit that detects, through image processing, a position of a feature portion from image data imaged and acquired when the feature portion of an object is positioned at the respective target positions by a moving mechanism; a position storage unit that stores the detected positions detected at the target positions in association with the respective target positions; and a display data generation unit that generates data for displaying information related to the detected positions on a display unit. The display data generation unit generates data for displaying the respective target positions and the respective detected positions, which are stored in association with the target positions, in the same coordinate space.





100
95
21
96
To 200
Command unit
Target position
From 104
40
Image acquisition
50
Image processing
10
Image data
20
Sampling position
60
Image data
10
80
Sampling position
Target position
22:
Feature image
30
21
20
35
Reference data
70
Evaluation processing
85
Display data generation
To 200
90
R1
Ri
Rn
Evaluation
Estimated factor
Countermeasure
RA
RB
RC

FIG. 1

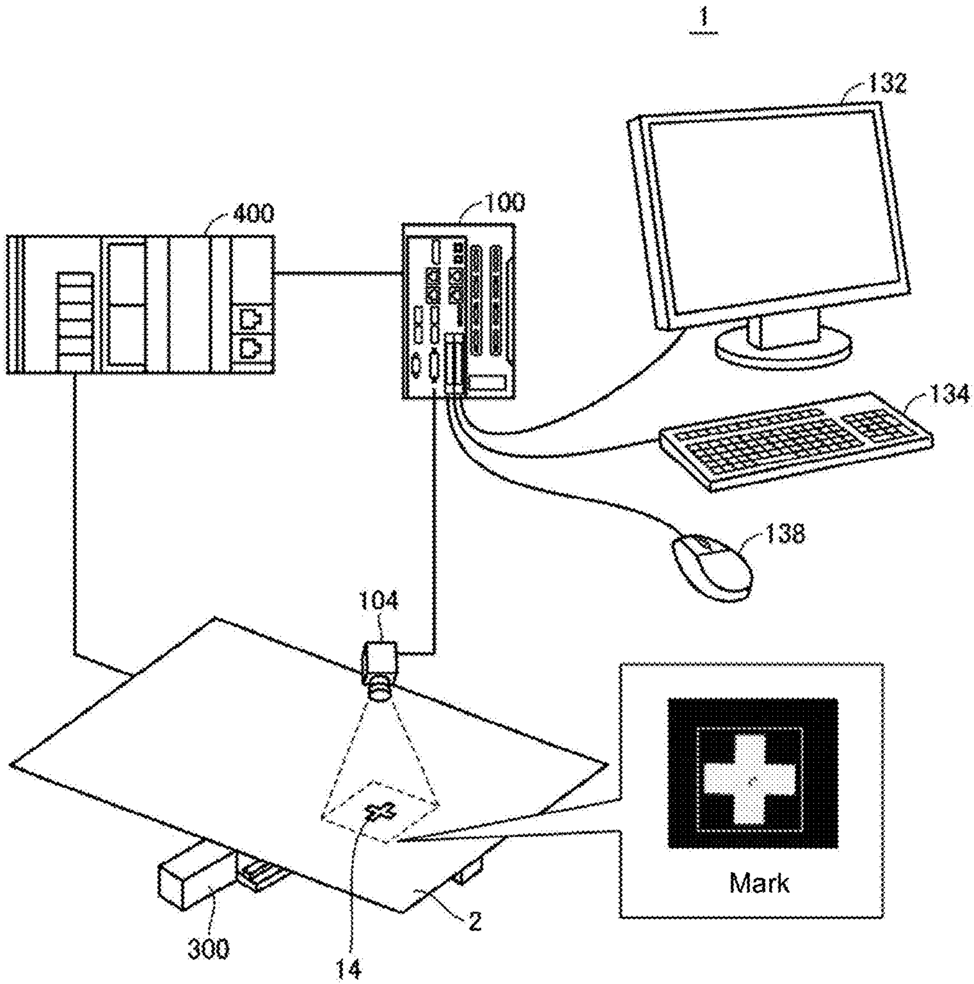


FIG. 2

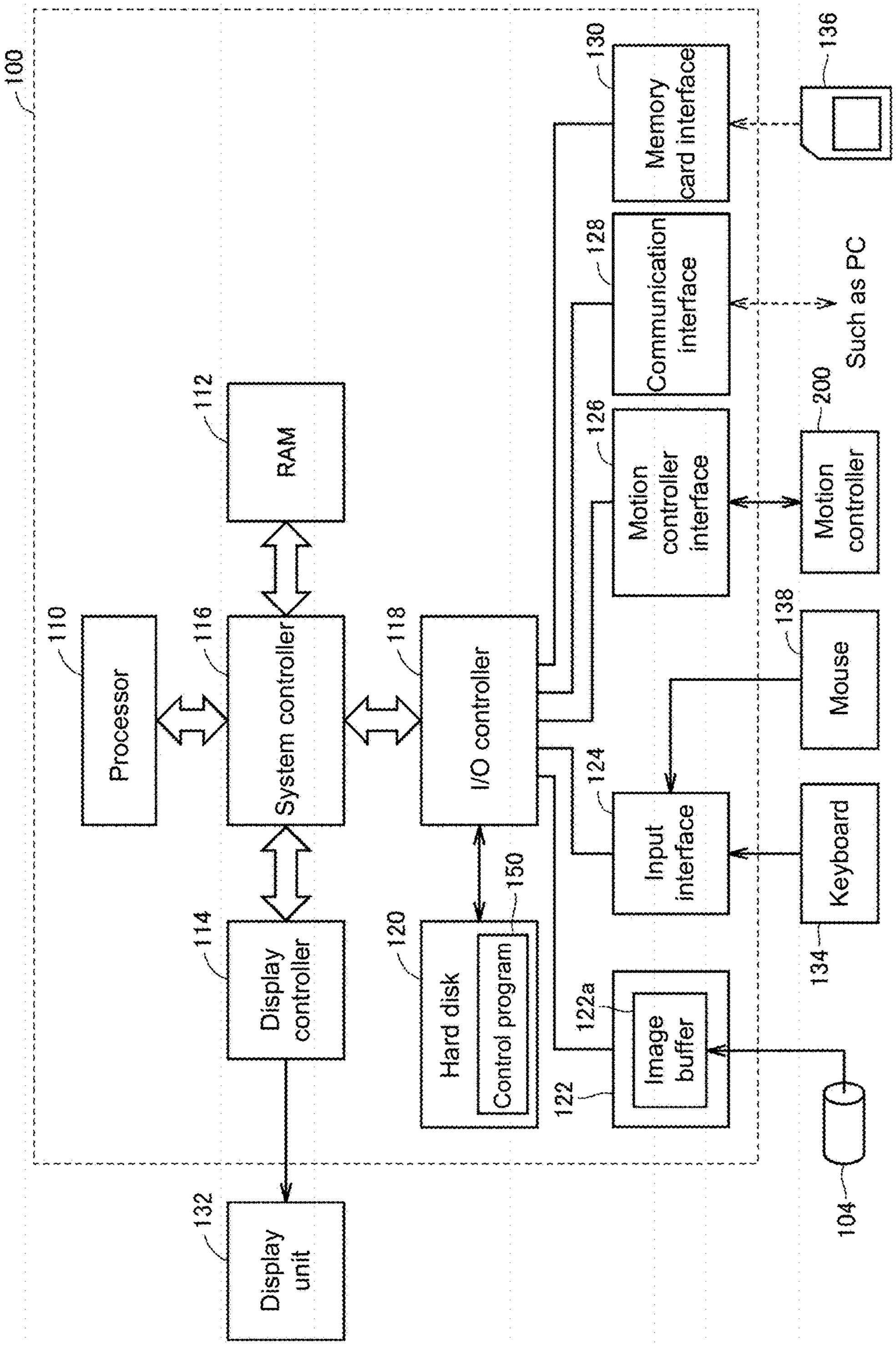

100
Processor
110
System controller
116
RAM
112
Display controller
114
I/O controller
118
Hard disk
120
Control program
150
Image buffer
122
122a
Input interface
124
Motion controller interface
126
Communication interface
128
Memory card interface
130
Display unit
132
Keyboard
134
Mouse
138
Motion controller
200
Such as PC
136
104

FIG. 3

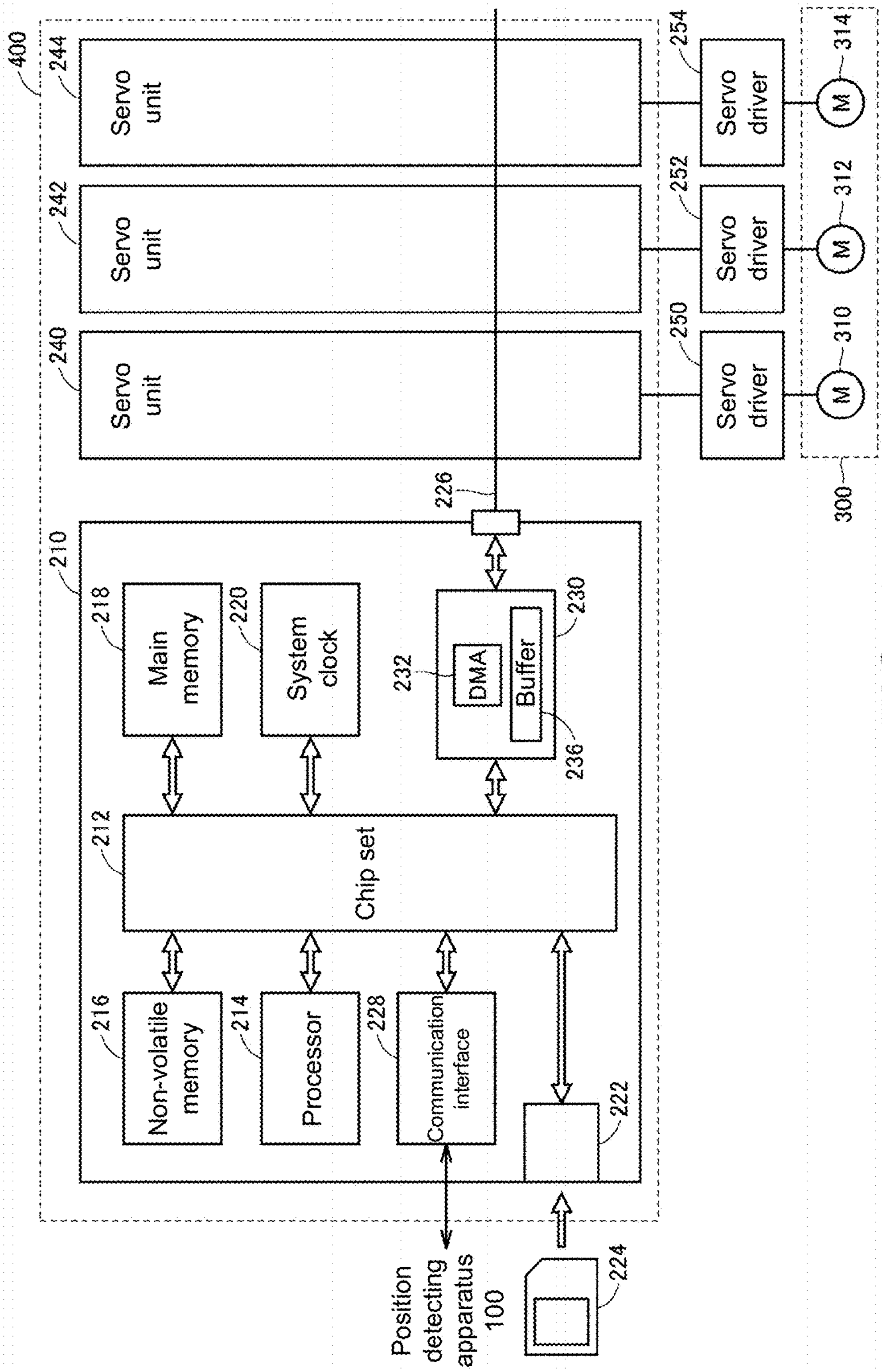

400
244
Servo unit
242
Servo unit
240
Servo unit
254
Servo driver
252
Servo driver
250
Servo driver
314
312
310
M
M
M
300
226
210
218
Main memory
220
System clock
230
232
DMA
Buffer
236
212
Chip set
216
Non-volatile memory
214
Processor
228
Communication interface
222
Position detecting apparatus 100
224

FIG. 4

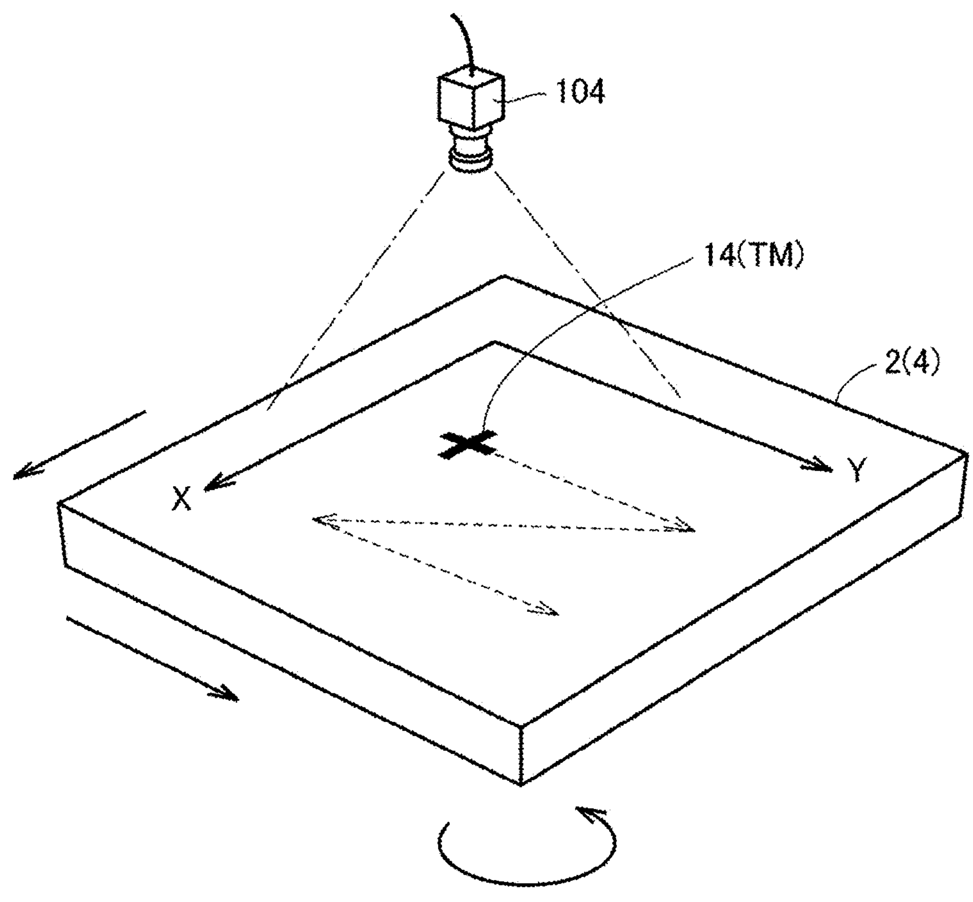


FIG. 5

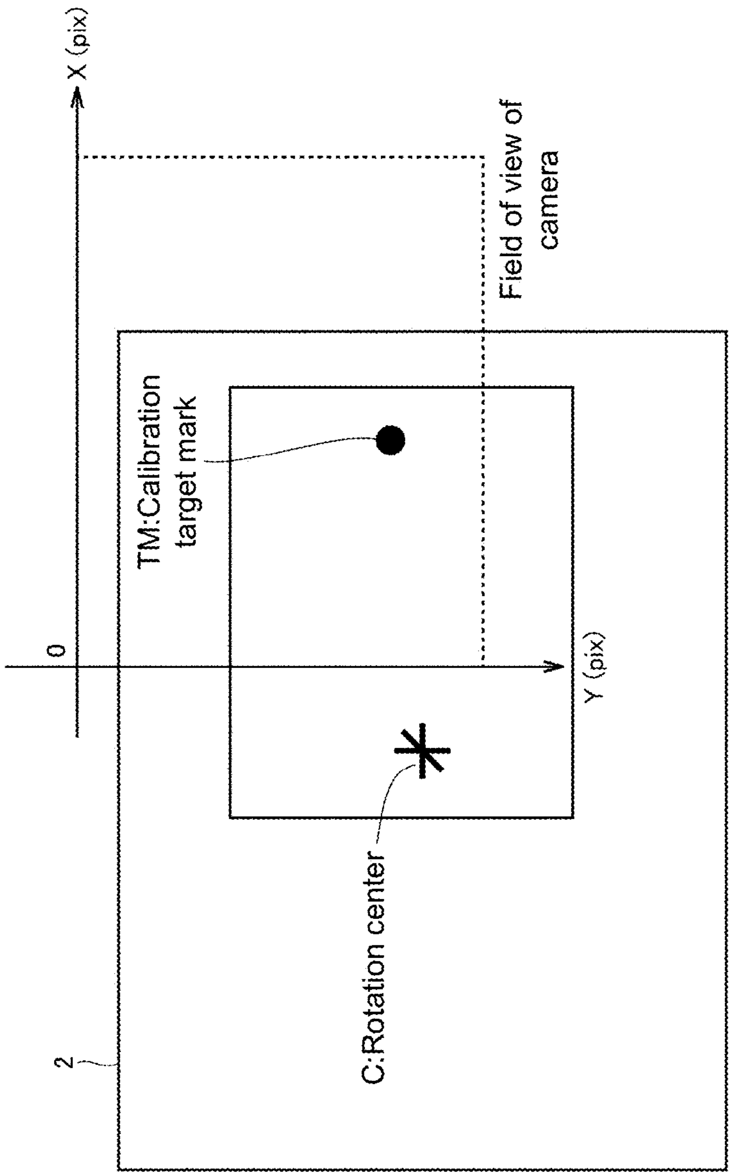

X (pix)
Y (pix)
0
Field of view of camera
TM:Calibration target mark
C:Rotation center
2

FIG. 6

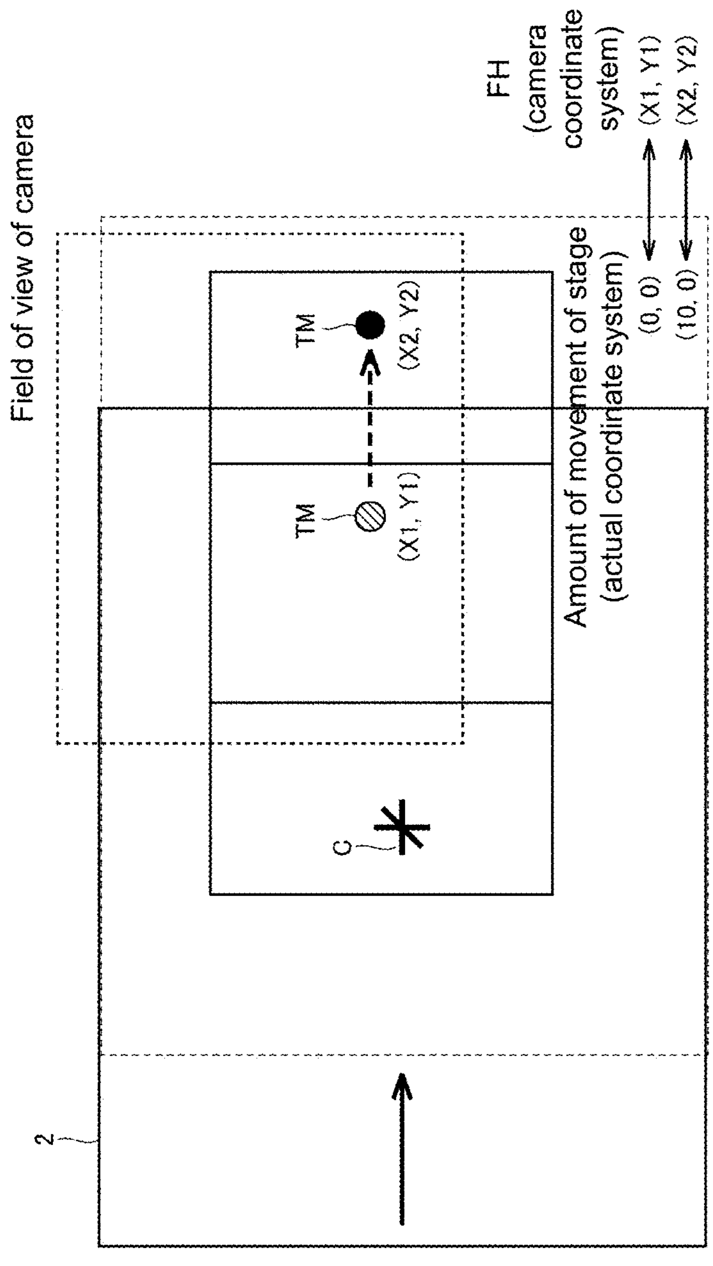

Field of view of camera
TM
(X2, Y2)
TM
(X1, Y1)
C
2
Amount of movement of stage
(actual coordinate system)
(0, 0)
(10, 0)
FH
(camera
coordinate
system)
(X1, Y1)
(X2, Y2)

FIG. 7

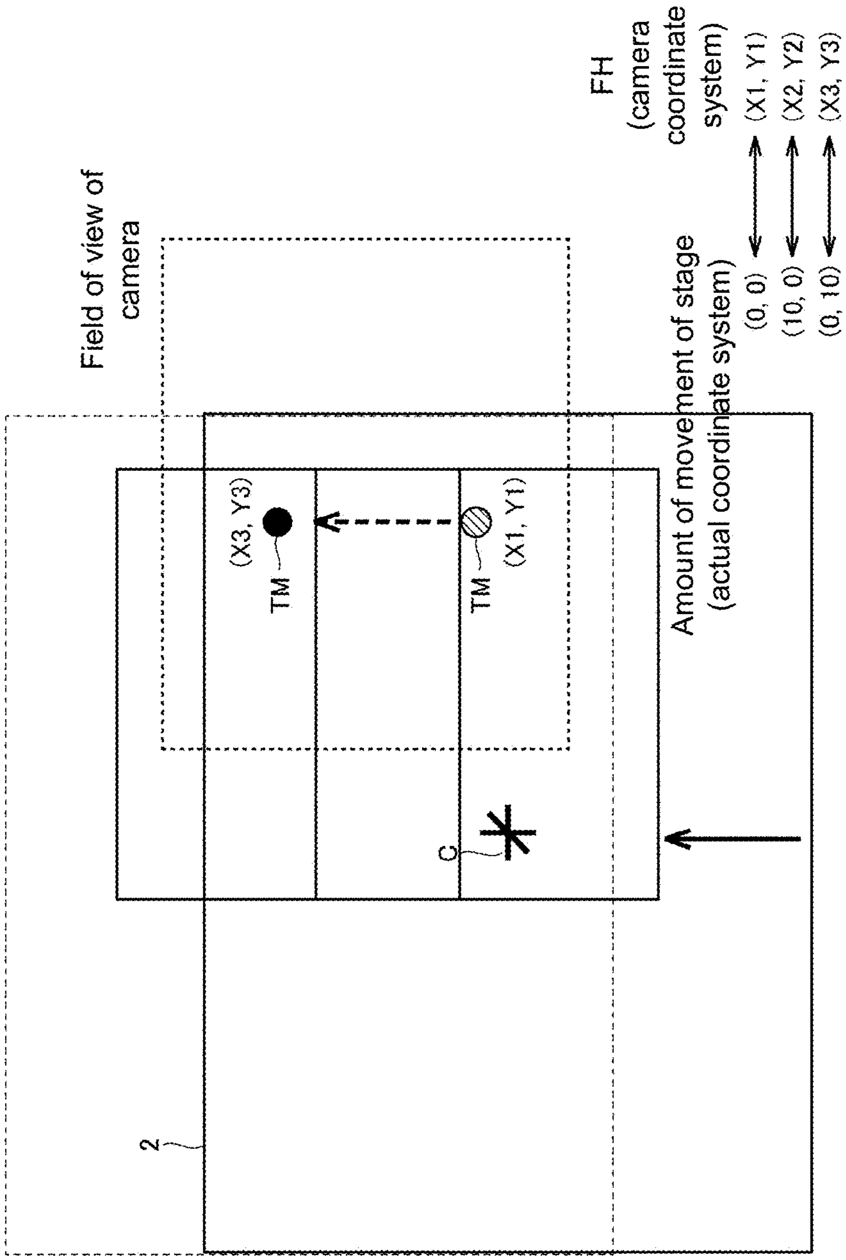

Field of view of camera
FH (camera coordinate system)
Amount of movement of stage (actual coordinate system)
(0, 0)
(10, 0)
(0, 10)
(X1, Y1)
(X2, Y2)
(X3, Y3)
TM
TM
(X3, Y3)
(X1, Y1)
C
2

FIG. 8

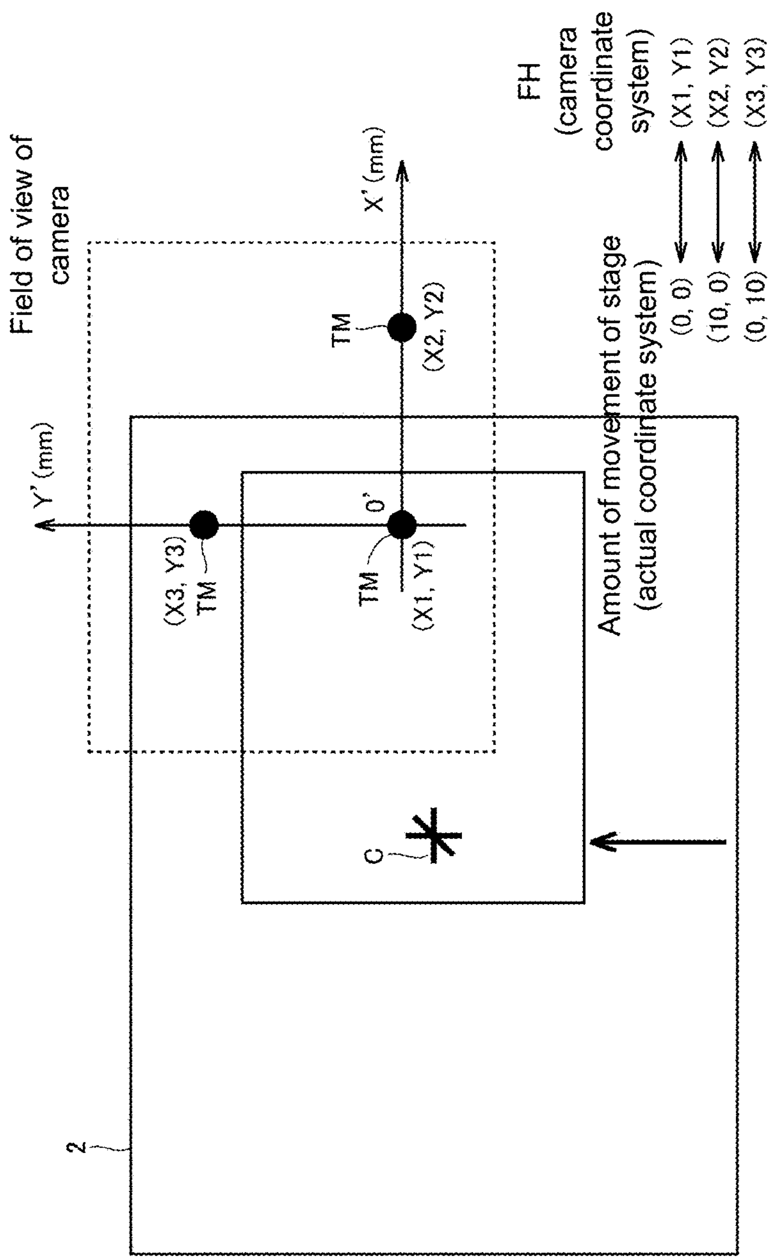

Field of view of camera
X' (mm)
Y' (mm)
TM
(X2, Y2)
(X3, Y3)
TM
0'
TM
(X1, Y1)
C
2
Amount of movement of stage (actual coordinate system)
(0, 0)
(10, 0)
(0, 10)
FH (camera coordinate system)
(X1, Y1)
(X2, Y2)
(X3, Y3)

FIG. 9

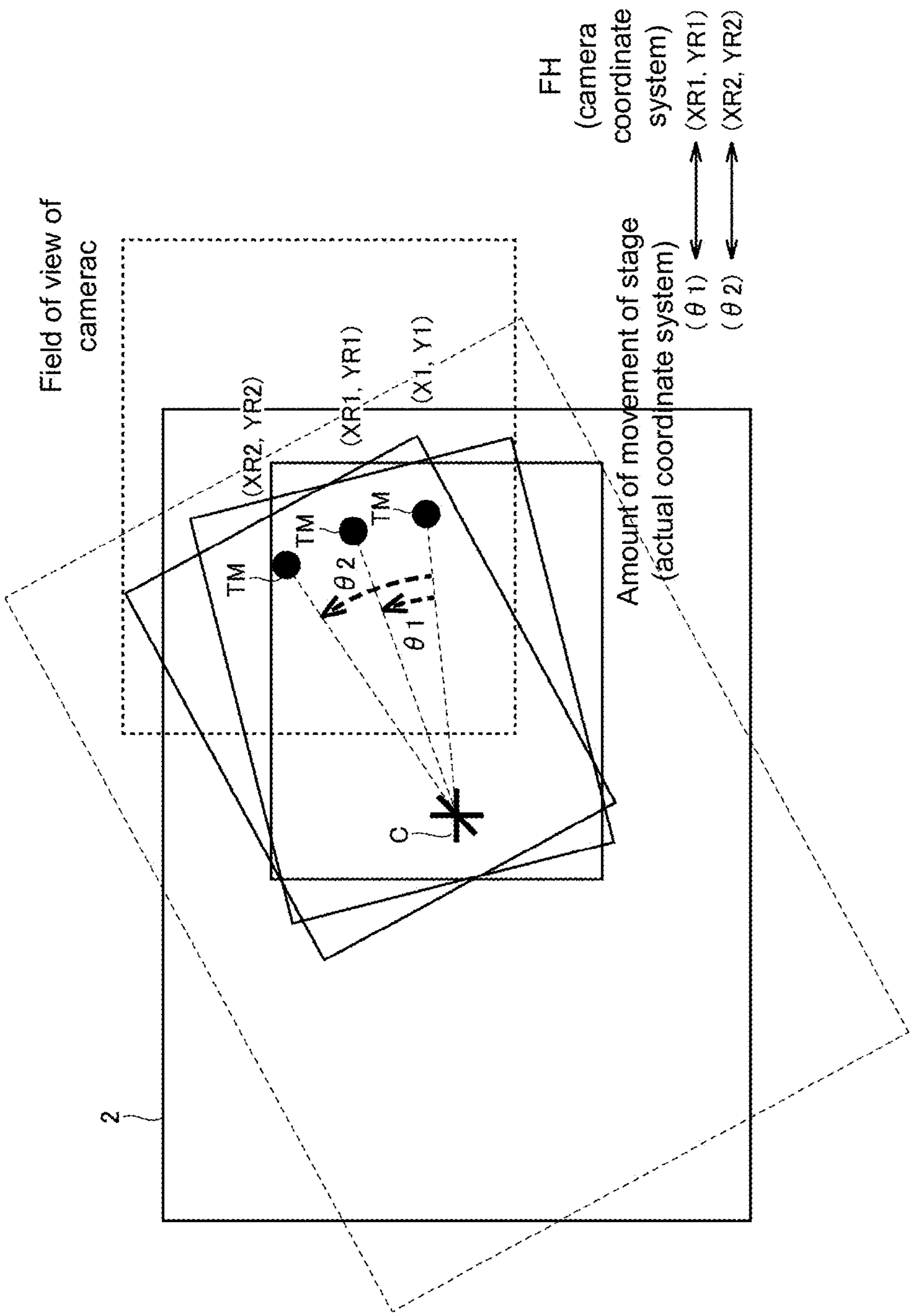

Field of view of
camerac
(XR2, YR2)
(XR1, YR1)
(X1, Y1)
TM
TM
TM
θ2
θ1
C
2
Amount of movement of stage
(actual coordinate system)
(θ1)
(θ2)
FH
(camera
coordinate
system)
(XR1, YR1)
(XR2, YR2)

FIG. 10

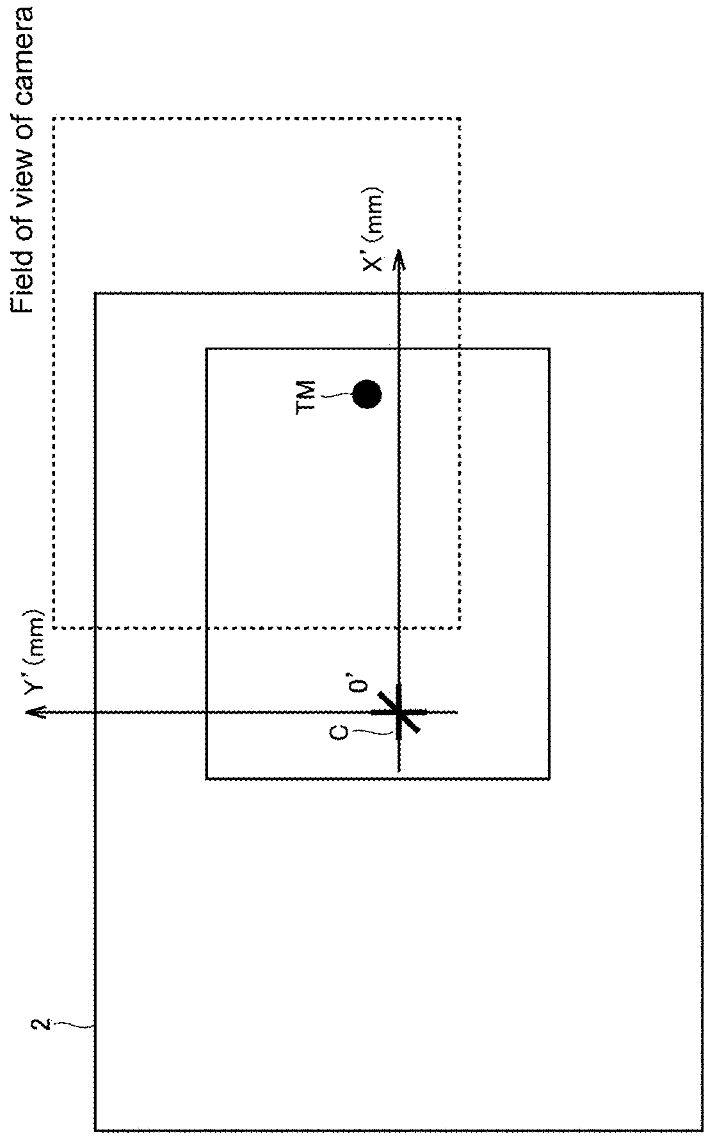


FIG. 11

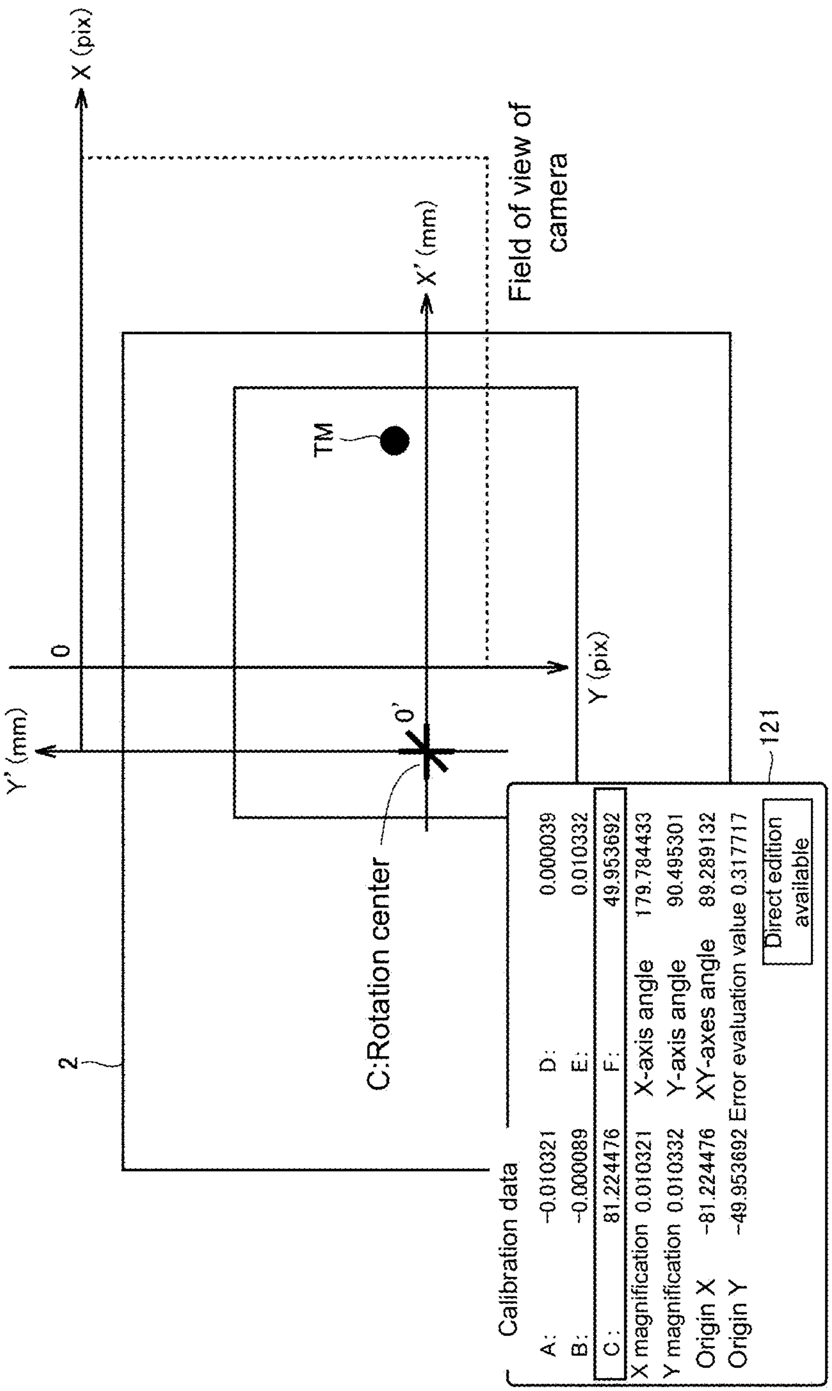

X (pix)
Field of view of camera
X' (mm)
TM
0
Y (pix)
Y' (mm)
0'
C:Rotation center
2
121
Calibration data
A: −0.010321 D: 0.000039
B: −0.000089 E: 0.010332
C: 81.224476 F: 49.953692
X magnification 0.010321 X-axis angle 179.784433
Y magnification 0.010332 Y-axis angle 90.495301
Origin X −81.224476 XY-axes angle 89.289132
Origin Y −49.953692 Error evaluation value 0.317717
Direct edition available

FIG. 12

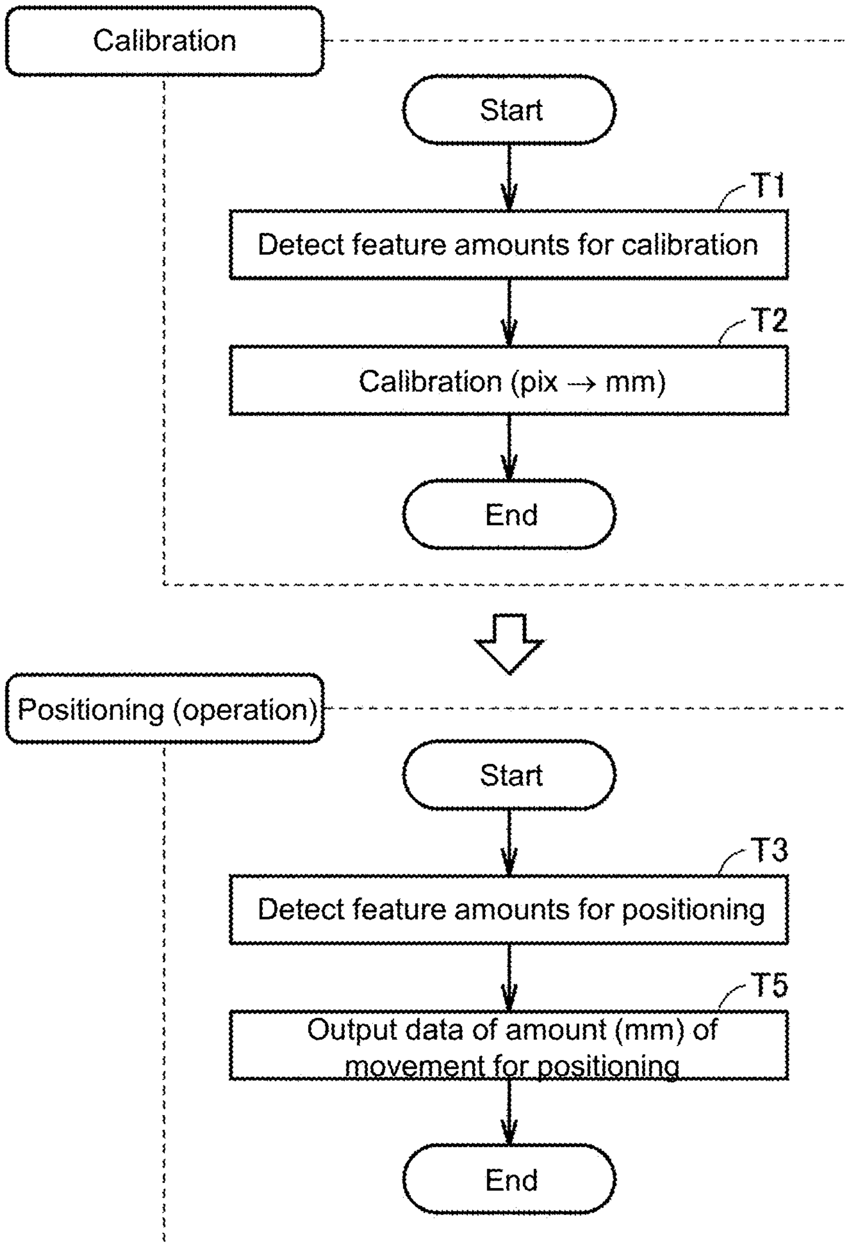

Calibration
Start
T1
Detect feature amounts for calibration
T2
Calibration (pix → mm)
End
Positioning (operation)
Start
T3
Detect feature amounts for positioning
T5
Output data of amount (mm) of movement for positioning
End

FIG. 13

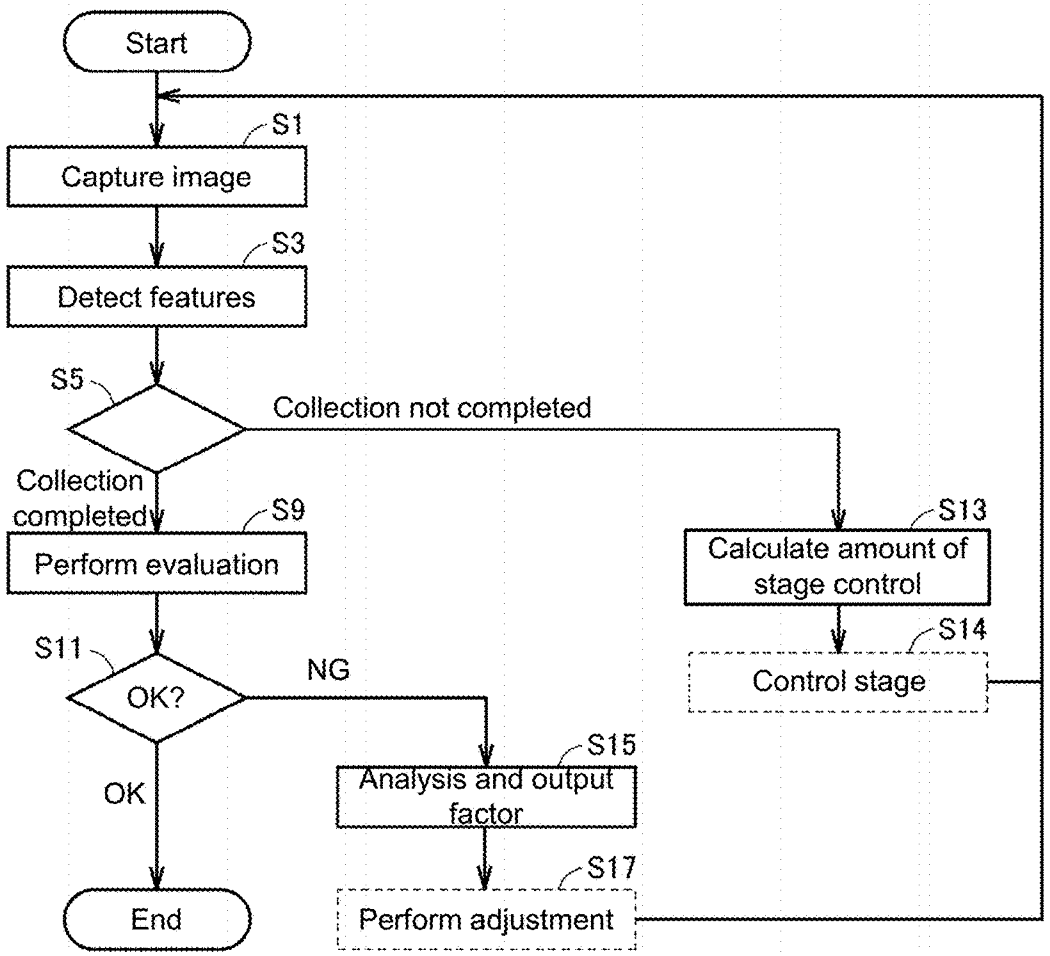
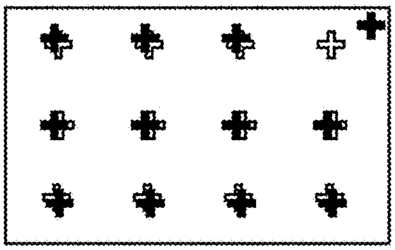

Start
S1
Capture image
S3
Detect features
S5
Collection not completed
Collection completed
S9
Perform evaluation
S11
OK?
NG
OK
End
S13
Calculate amount of stage control
S14
Control stage
S15
Analysis and output factor
S17
Perform adjustment

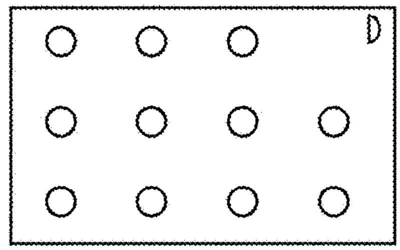
FIG. 14



White: target position

Black: sampling position

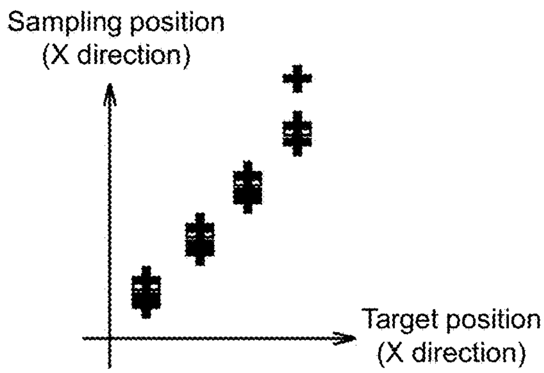
FIG. 15A



:Feature image

:Background image

FIG. 15B



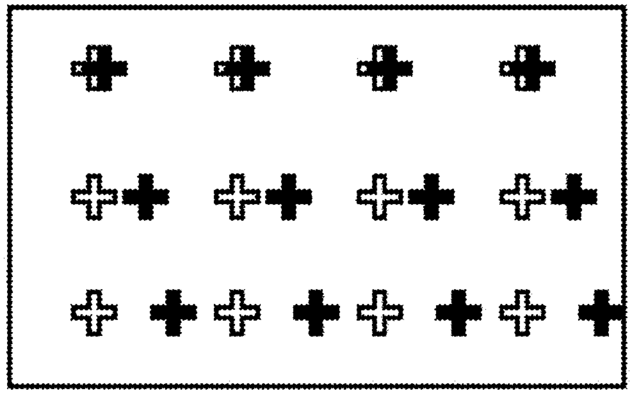
White: target position

Black: sampling position

FIG. 15C

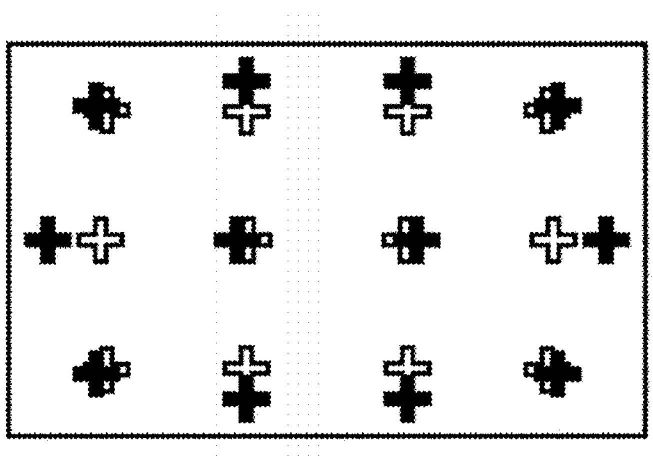
X direction (target position)	Minimum error	Maximum error
10	3	4
20	3	5
30	1	3
40	3	20

FIG. 15D



White: target position Black: sampling position

FIG. 16



White: target position Black: sampling position

FIG. 17

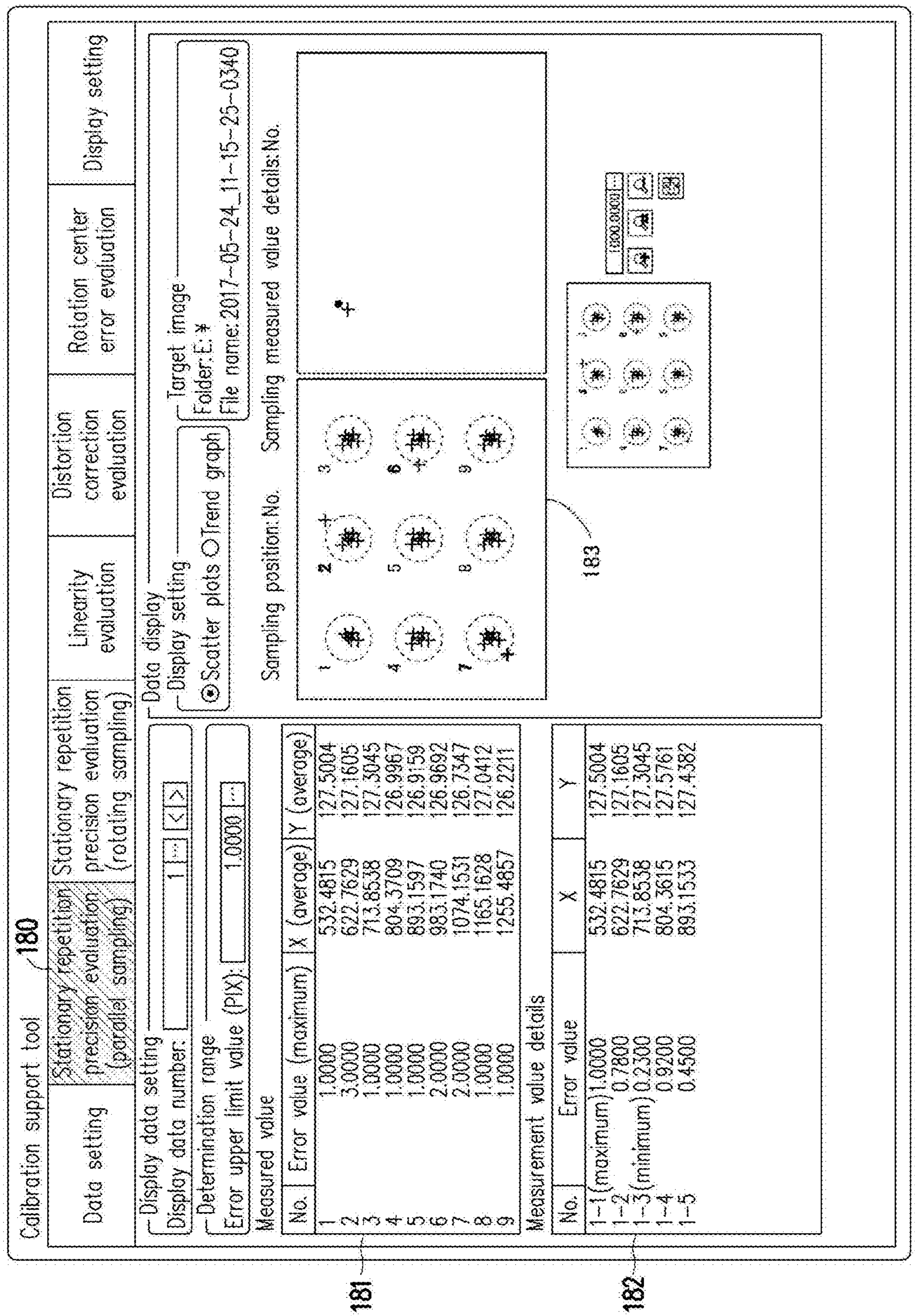
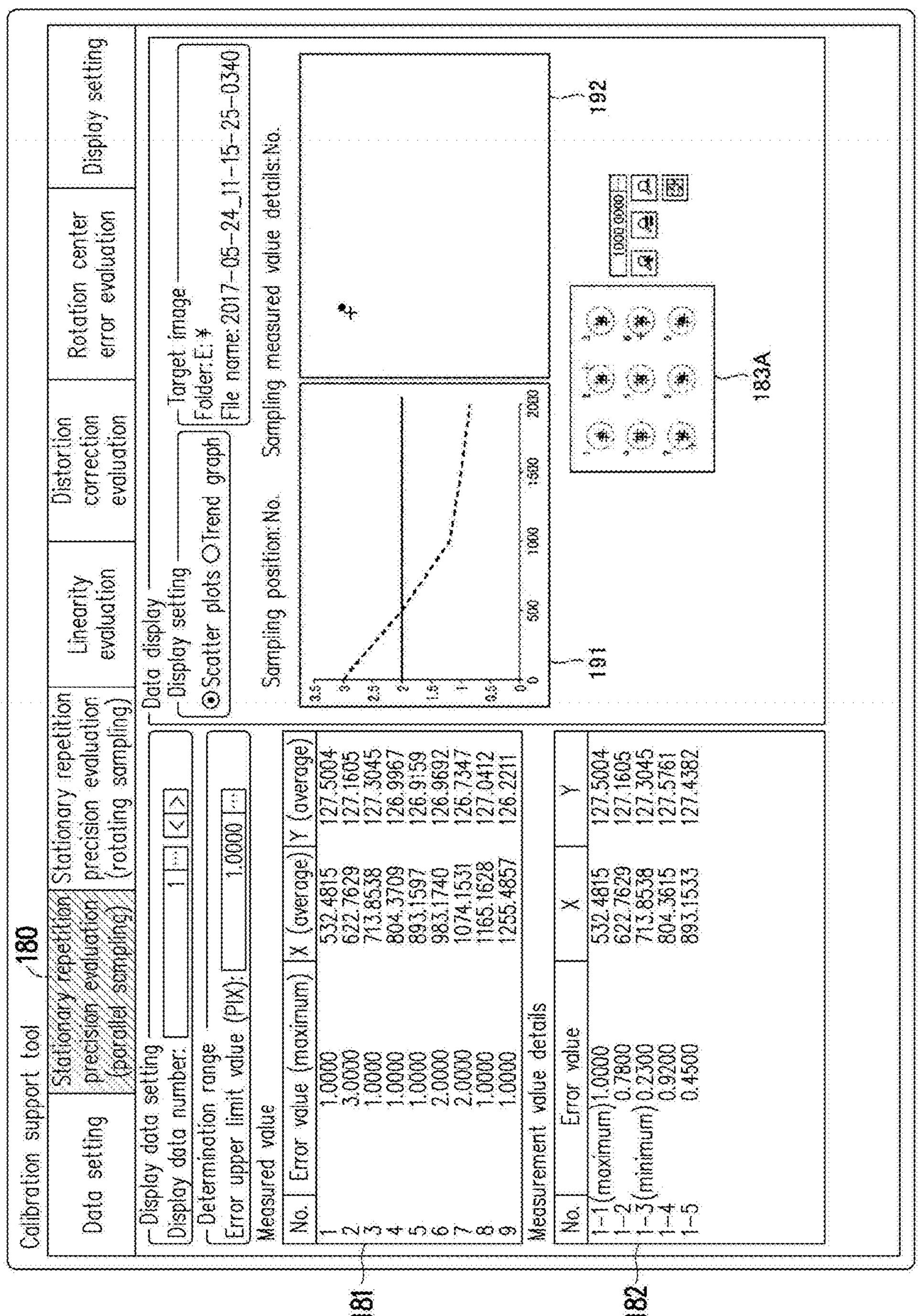

180
181
182
183
Calibration support tool
Data setting
Stationary repetition precision evaluation (parallel sampling)
Stationary repetition precision evaluation (rotating sampling)
Linearity evaluation
Distortion correction evaluation
Rotation center error evaluation
Display setting
Display data setting
Display data number:
Determination range
Error upper limit value (PIX):
1.0000
Measured value
No.
Error value (maximum)
X (average)
Y (average)
1 1.0000 532.4815 127.5004
2 3.0000 622.7629 127.1605
3 1.0000 713.8538 127.3045
4 1.0000 804.3709 126.9967
5 1.0000 893.1597 126.9159
6 2.0000 983.1740 126.9692
7 2.0000 1074.1531 126.7347
8 1.0000 1165.1628 127.0412
9 1.0000 1255.4857 126.2211
Measurement value details
No.
Error value
X
Y
1-1(maximum) 1.0000 532.4815 127.5004
1-2 0.7800 622.7629 127.1605
1-3(minimum) 0.2300 713.8538 127.3045
1-4 0.9200 804.3615 127.5761
1-5 0.4500 893.1533 127.4382
Data display
Display setting
Scatter plots
Trend graph
Target image
Folder: E: *
File name: 2017-05-24_11-15-25-0340
Sampling position: No.
Sampling measured value details: No.

FIG. 18



180
Calibration support tool
Data setting
Stationary repetition precision evaluation (parallel sampling)
Stationary repetition precision evaluation (rotating sampling)
Linearity evaluation
Distortion correction evaluation
Rotation center error evaluation
Display setting
Display data setting
Display data number:
Determination range
Error upper limit value (PIX):
1.0000
Measured value
No.
Error value (maximum)
X (average)
Y (average)
1 1.0000 532.4815 127.5004
2 3.0000 622.7629 127.1605
3 1.0000 713.8538 127.3045
4 1.0000 804.3709 126.9967
5 1.0000 893.1597 126.9159
6 2.0000 983.1740 126.9692
7 2.0000 1074.1531 126.7347
8 1.0000 1165.1628 127.0412
9 1.0000 1255.4857 126.2211
Measurement value details
No.
Error value
X
Y
1-1(maximum) 1.0000 532.4815 127.5004
1-2 0.7800 622.7629 127.1605
1-3(minimum) 0.2300 713.8538 127.3045
1-4 0.9200 804.3615 127.5761
1-5 0.4500 893.1533 127.4382
Data display
Display setting
Scatter plots
Trend graph
Target image
Folder:E:¥
File name:2017-05-24_11-15-25-0340
Sampling position:No.
Sampling measured value details:No.
181
182
191
192
183A

FIG. 19

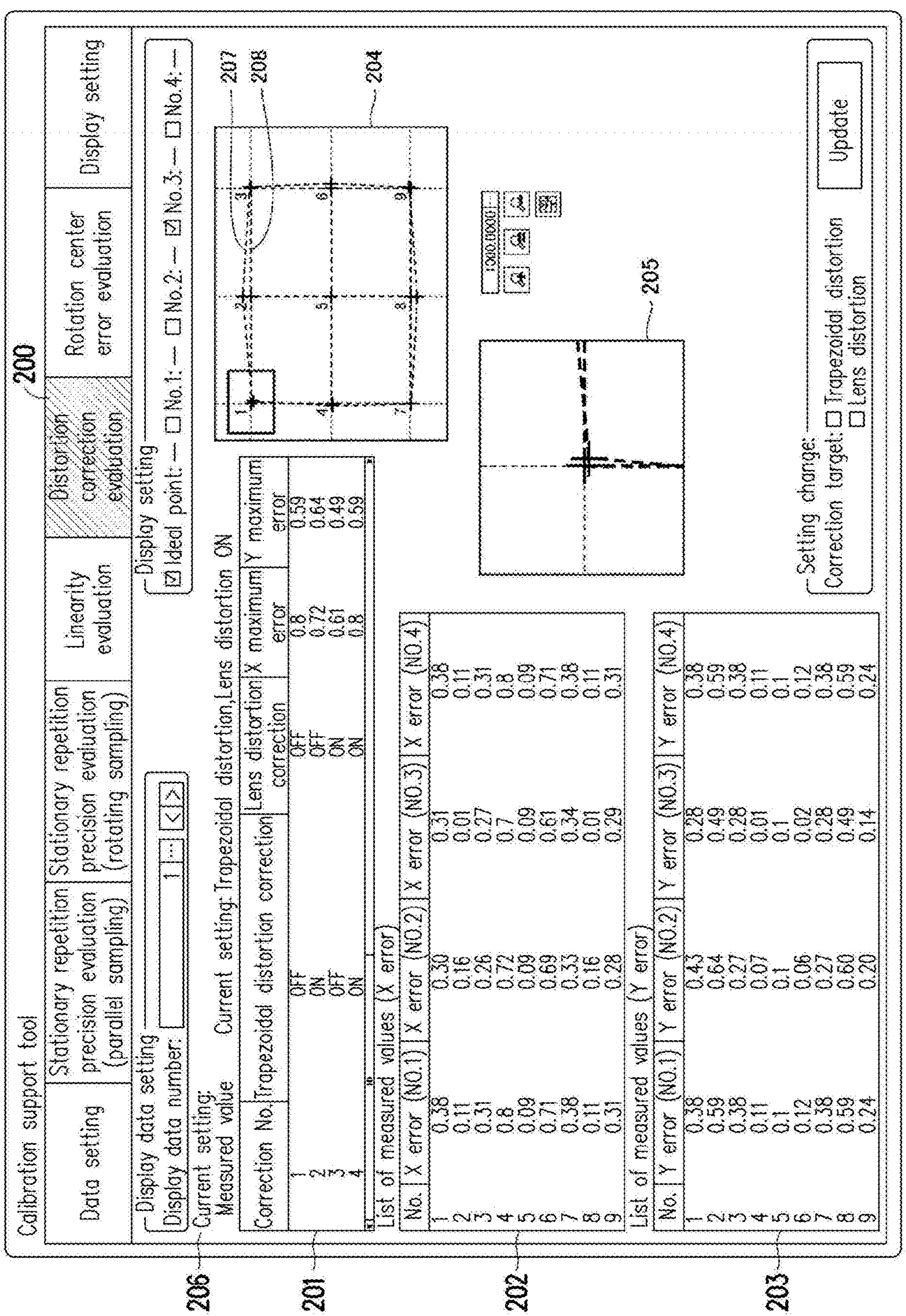
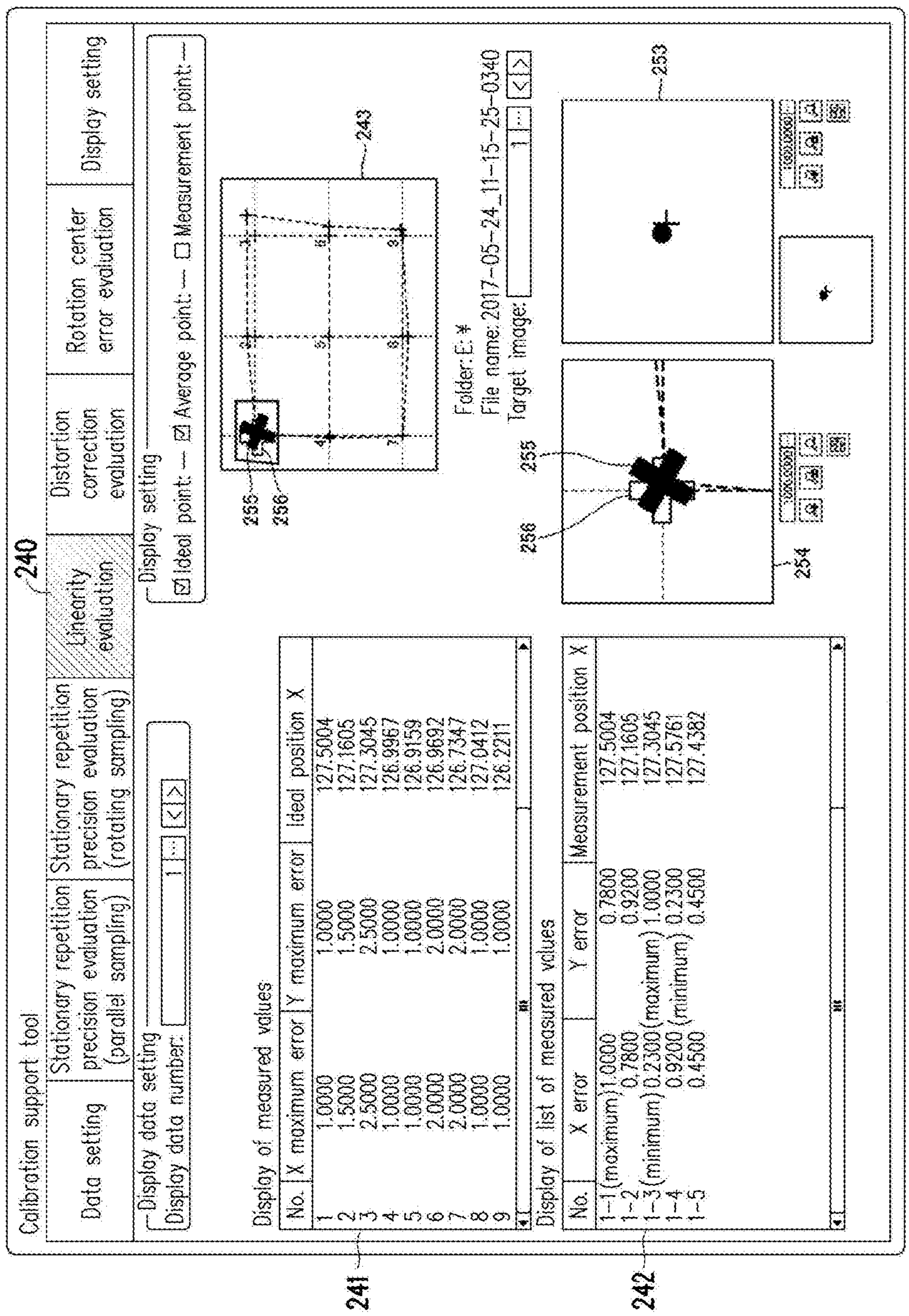

200
Calibration support tool
Data setting
Stationary repetition precision evaluation (parallel sampling)
Stationary repetition precision evaluation (rotating sampling)
Linearity evaluation
Distortion correction evaluation
Rotation center error evaluation
Display setting
Display data setting
Display data number:
1
Current setting:
Measured value
Current setting: Trapezoidal distortion,Lens distortion ON
Correction No.
Trapezoidal distortion correction
Lens distortion correction
X maximum error
Y maximum error
1 OFF OFF 0.8 0.59
2 ON OFF 0.72 0.64
3 OFF ON 0.61 0.49
4 ON ON 0.8 0.59
List of measured values (X error)
No.
X error (NO.1)
X error (NO.2)
X error (NO.3)
X error (NO.4)
1 0.38 0.30 0.31 0.38
2 0.11 0.16 0.01 0.11
3 0.31 0.26 0.27 0.31
4 0.8 0.72 0.7 0.8
5 0.09 0.09 0.09 0.09
6 0.71 0.69 0.61 0.71
7 0.38 0.33 0.34 0.38
8 0.11 0.16 0.01 0.11
9 0.31 0.28 0.29 0.31
List of measured values (Y error)
No.
Y error (NO.1)
Y error (NO.2)
Y error (NO.3)
Y error (NO.4)
1 0.38 0.43 0.28 0.38
2 0.59 0.64 0.49 0.59
3 0.38 0.27 0.28 0.38
4 0.11 0.07 0.01 0.11
5 0.1 0.1 0.1 0.1
6 0.12 0.06 0.02 0.12
7 0.38 0.27 0.28 0.38
8 0.59 0.60 0.49 0.59
9 0.24 0.20 0.14 0.24
Display setting
Ideal point: ---
No.1: ---
No.2: ---
No.3: ---
No.4: ---
207
208
204
205
1 2 3 4 5 6 7 8 9
Setting change:
Correction target:
Trapezoidal distortion
Lens distortion
Update
206
201
202
203

FIG. 20



240
Calibration support tool
Data setting
Stationary repetition precision evaluation (parallel sampling)
Stationary repetition precision evaluation (rotating sampling)
Linearity evaluation
Distortion correction evaluation
Rotation center error evaluation
Display setting
Display data setting
Display data number:
Display setting
Ideal point: —
Average point: —
Measurement point: —
Display of measured values
No.
X maximum error
Y maximum error
Ideal position X
1 1.0000 1.0000 127.5004
2 1.5000 1.5000 127.1605
3 2.5000 2.5000 127.3045
4 1.0000 1.0000 126.9967
5 1.0000 1.0000 126.9159
6 2.0000 2.0000 126.9692
7 2.0000 2.0000 126.7347
8 1.0000 1.0000 127.0412
9 1.0000 1.0000 126.2211
Display of list of measured values
No.
X error
Y error
Measurement position X
1-1 (maximum) 1.0000 0.7800 127.5004
1-2 0.7800 0.9200 127.1605
1-3 (minimum) 0.2300 (maximum) 1.0000 127.3045
1-4 0.9200 (minimum) 0.2300 127.5761
1-5 0.4500 0.4500 127.4382
Folder: E: *
File name: 2017-05-24_11-15-25-0340
Target image:
241
242
243
253
254
255
256

FIG. 21

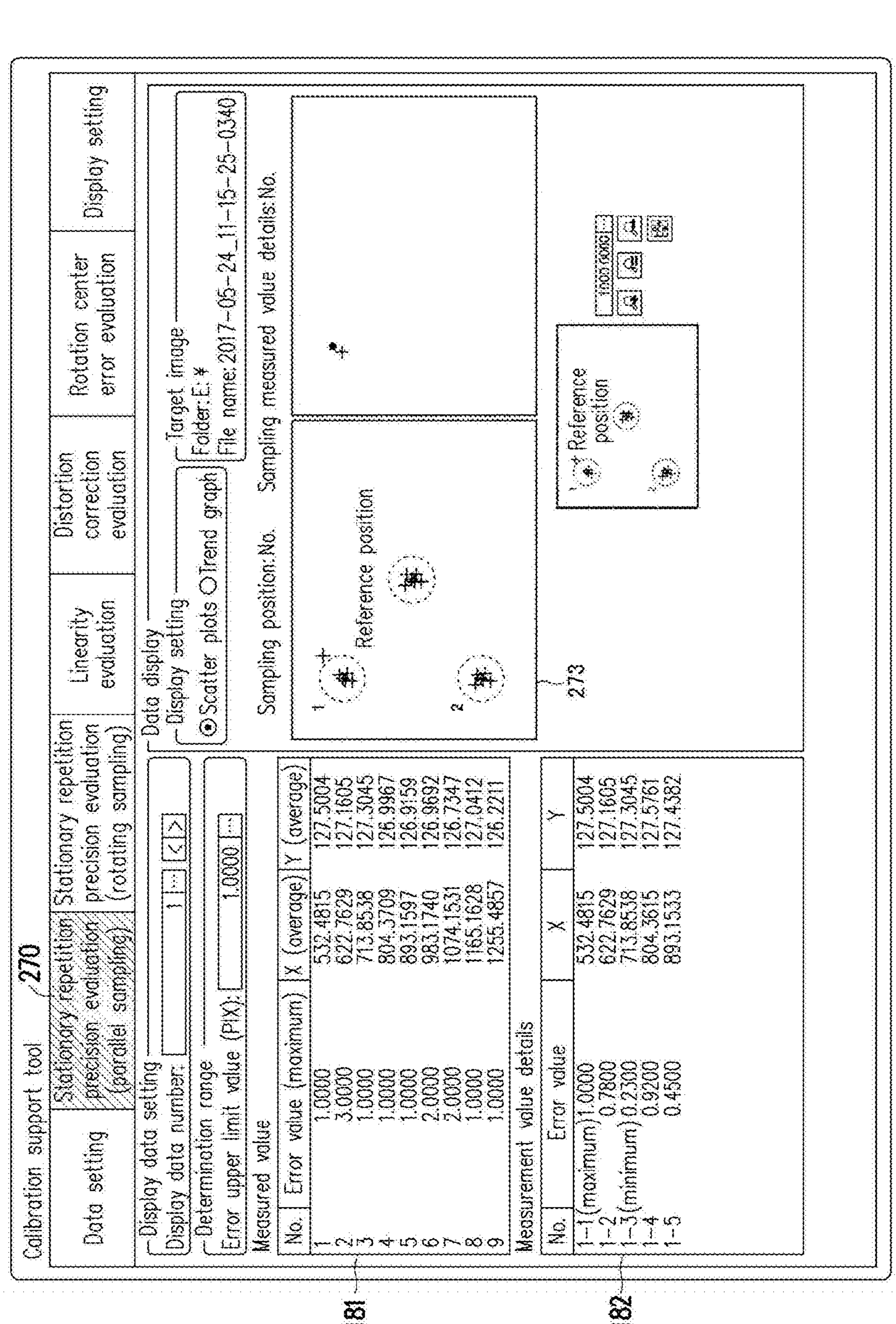

Calibration support tool
270
Data setting
Stationary repetition precision evaluation (parallel sampling)
Stationary repetition precision evaluation (rotating sampling)
Linearity evaluation
Distortion correction evaluation
Rotation center error evaluation
Display setting
Display data setting
Display data number: 1
Determination range
Error upper limit value (PIX): 1.0000
Measured value
No. Error value (maximum) X (average) Y (average)
1 1.0000 532.4815 127.5004
2 3.0000 622.7629 127.1605
3 1.0000 713.8538 127.3045
4 1.0000 804.3709 126.9967
5 1.0000 893.1597 126.9159
6 2.0000 983.1740 126.9692
7 2.0000 1074.1531 126.7347
8 1.0000 1165.1628 127.0412
9 1.0000 1255.4857 126.2211
Measurement value details
No. Error value X Y
1-1 (maximum) 1.0000 532.4815 127.5004
1-2 0.7800 622.7629 127.1605
1-3 (minimum) 0.2300 713.8538 127.3045
1-4 0.9200 804.3615 127.5761
1-5 0.4500 893.1533 127.4382
Data display
Display setting
Scatter plots
Trend graph
Target image
Folder: E: *
File name: 2017-05-24_11-15-25-0340
Sampling position: No.
Sampling measured value details: No.
Reference position
273
181
182

FIG. 22

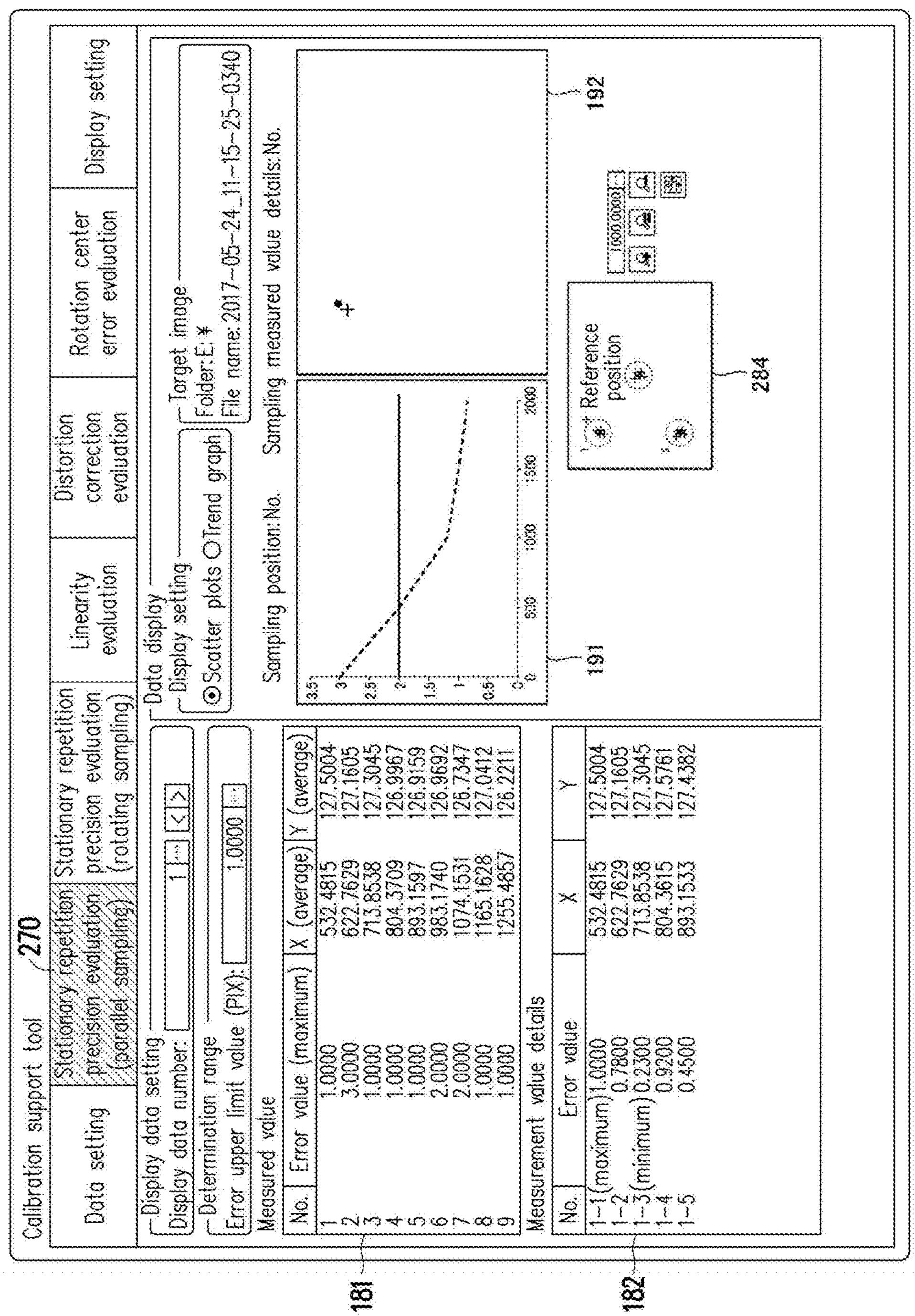

Calibration support tool
270
Data setting
Stationary repetition precision evaluation (parallel sampling)
Stationary repetition precision evaluation (rotating sampling)
Linearity evaluation
Distortion correction evaluation
Rotation center error evaluation
Display setting
Display data setting
Display data number: 1
Determination range
Error upper limit value (PIX): 1.0000
Measured value
No. | Error value (maximum) | X (average) | Y (average)
1 | 1.0000 | 532.4815 | 127.5004
2 | 3.0000 | 622.7629 | 127.1605
3 | 1.0000 | 713.8538 | 127.3045
4 | 1.0000 | 804.3709 | 126.9967
5 | 1.0000 | 893.1597 | 126.9159
6 | 2.0000 | 983.1740 | 126.9692
7 | 2.0000 | 1074.1531 | 126.7347
8 | 1.0000 | 1165.1628 | 127.0412
9 | 1.0000 | 1255.4857 | 126.2211
Measurement value details
No. | Error value | X | Y
1-1 (maximum) | 1.0000 | 532.4815 | 127.5004
1-2 | 0.7800 | 622.7629 | 127.1605
1-3 (minimum) | 0.2300 | 713.8538 | 127.3045
1-4 | 0.9200 | 804.3615 | 127.5761
1-5 | 0.4500 | 893.1533 | 127.4382
Data display
Display setting
Scatter plots
Trend graph
Target image
Folder: E: *
File name: 2017-05-24_11-15-25-0340
Sampling position: No.
Sampling measured value details: No.
3.5
3
2.5
2
1.5
1
0.5
0
0
500
1000
1500
2000
191
192
Reference position
284
181
182

FIG. 23

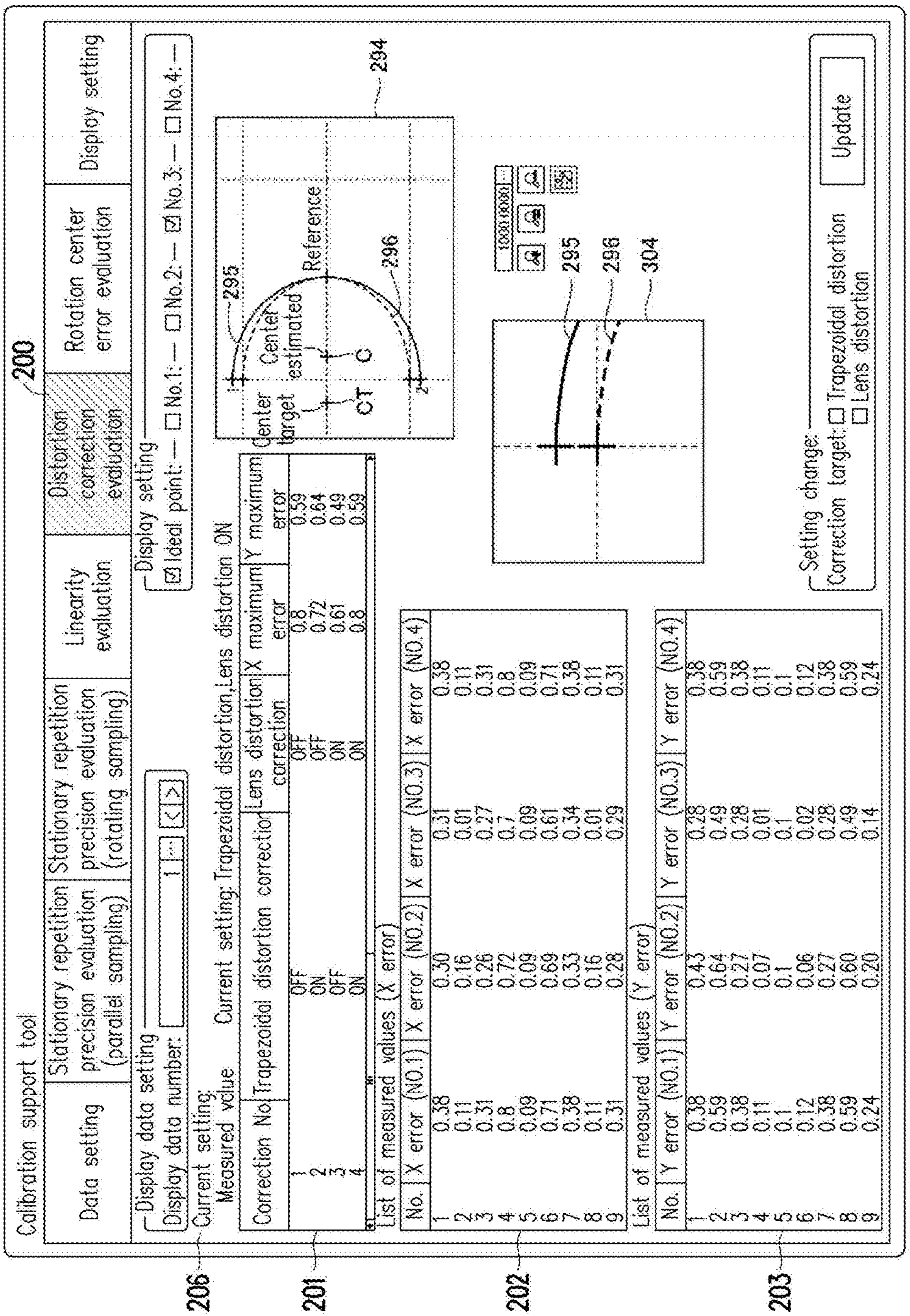

200
Calibration support tool
Data setting
Stationary repetition precision evaluation (parallel sampling)
Stationary repetition precision evaluation (rotating sampling)
Linearity evaluation
Distortion correction evaluation
Rotation center error evaluation
Display setting
Display data setting
Display data number:
Display setting
☑ Ideal point: — ☐ No.1: — ☐ No.2: — ☑ No.3: — ☐ No.4: —
Current setting:
Measured value
Current setting: Trapezoidal distortion,Lens distortion ON
Correction No
Trapezoidal distortion correction
Lens distortion correction
X maximum error
Y maximum error
1 OFF OFF 0.8 0.59
2 ON OFF 0.72 0.64
3 OFF ON 0.61 0.49
4 ON ON 0.8 0.59
List of measured values (X error)
No. X error (NO.1) X error (NO.2) X error (NO.3) X error (NO.4)
1 0.38 0.30 0.31 0.38
2 0.11 0.16 0.01 0.11
3 0.31 0.26 0.27 0.31
4 0.8 0.72 0.7 0.8
5 0.09 0.09 0.09 0.09
6 0.71 0.69 0.61 0.71
7 0.38 0.33 0.34 0.38
8 0.11 0.16 0.01 0.11
9 0.31 0.28 0.29 0.31
List of measured values (Y error)
No. Y error (NO.1) Y error (NO.2) Y error (NO.3) Y error (NO.4)
1 0.38 0.43 0.28 0.38
2 0.59 0.64 0.49 0.59
3 0.38 0.27 0.28 0.38
4 0.11 0.07 0.01 0.11
5 0.1 0.1 0.1 0.1
6 0.12 0.06 0.02 0.12
7 0.38 0.27 0.28 0.38
8 0.59 0.60 0.49 0.59
9 0.24 0.20 0.14 0.24
Center target
CT
Center estimated
C
Reference
295
296
294
304
Setting change:
Correction target: ☐ Trapezoidal distortion
☐ Lens distortion
Update
206
201
202
203

FIG. 24

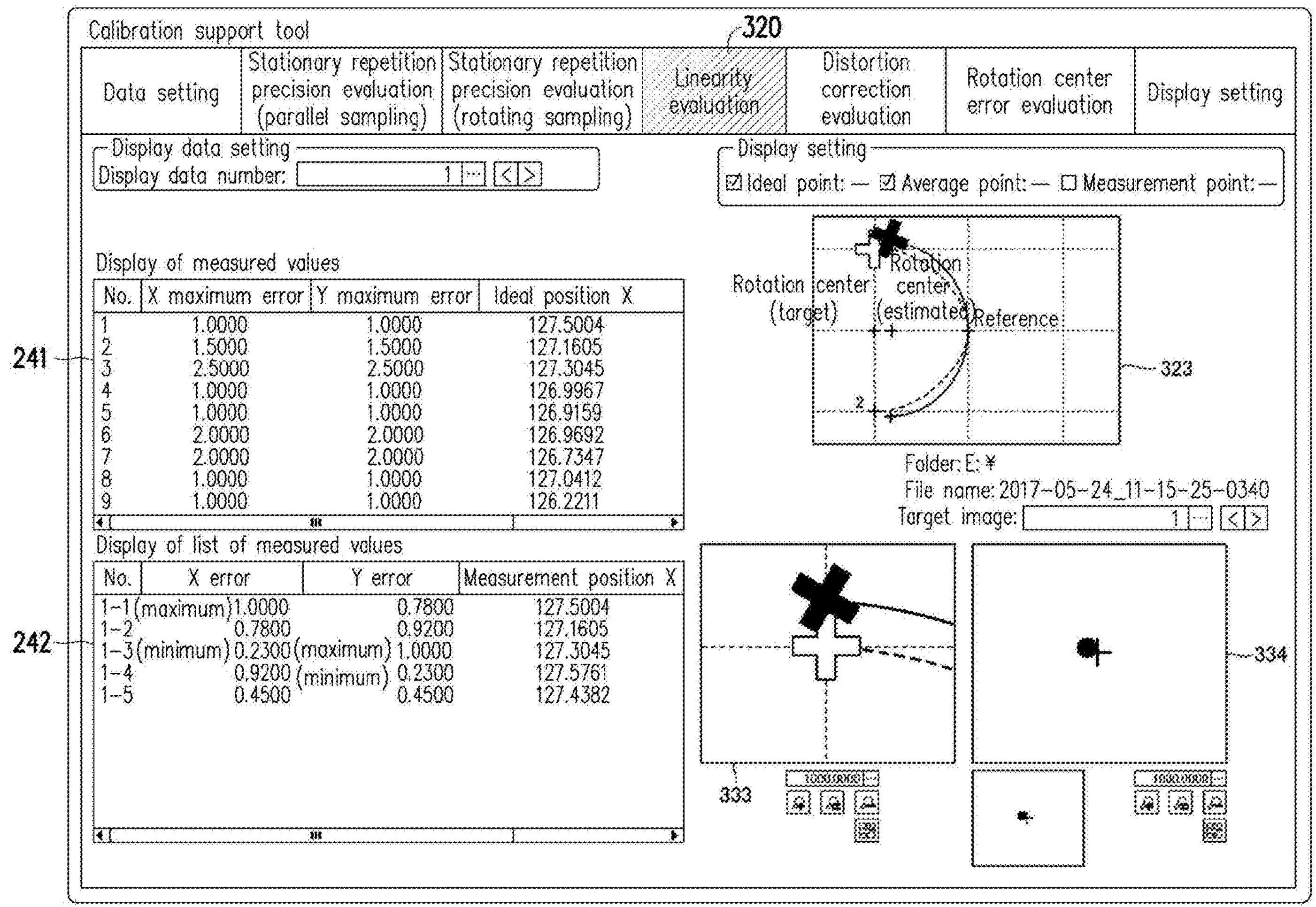

Calibration support tool
320
Data setting
Stationary repetition precision evaluation (parallel sampling)
Stationary repetition precision evaluation (rotating sampling)
Linearity evaluation
Distortion correction evaluation
Rotation center error evaluation
Display setting
Display data setting
Display data number: 1
Display setting
☑ Ideal point: — ☑ Average point: — ☐ Measurement point: —
Display of measured values
No. | X maximum error | Y maximum error | Ideal position X
1 1.0000 1.0000 127.5004
2 1.5000 1.5000 127.1605
3 2.5000 2.5000 127.3045
4 1.0000 1.0000 126.9967
5 1.0000 1.0000 126.9159
6 2.0000 2.0000 126.9692
7 2.0000 2.0000 126.7347
8 1.0000 1.0000 127.0412
9 1.0000 1.0000 126.2211
Display of list of measured values
No. | X error | Y error | Measurement position X
1-1 (maximum) 1.0000 0.7800 127.5004
1-2 0.7800 0.9200 127.1605
1-3 (minimum) 0.2300 (maximum) 1.0000 127.3045
1-4 0.9200 (minimum) 0.2300 127.5761
1-5 0.4500 0.4500 127.4382
241
242
Rotation center (target)
Rotation center (estimated)
Reference
2
323
Folder: E:¥
File name: 2017-05-24_11-15-25-0340
Target image: 1
333
334

FIG. 25

	Evaluation	Estimated factor and countermeasure
R1	RA Points at which target positions and sampling positions do not coincide are present	■ Background part outside target mark is erroneously detected at inconsistent point RB → Adjust search setting (model, setting parameter, and the like) RC
R2	RA Amounts of deviations of sampling positions increase in X direction by specific amount (amounts of movement do not coincide with measurement results)	■ Amount of movement of stage is inappropriate RA → Check stage control RB
R3	RA Point at which target position do not coincide with sampling position is present at end of image	■ Influence of camera lens distortion RA → Change lens to lens with no distortion in field of view RB

FIG. 26

	Evaluation	Estimated factor and countermeasure
R4	RA Variations in samplings are large	■ Is setting of detection unit (search or the like) for sampling inappropriate, and hasn't sampling been able to be constantly performed at same position? RB → Adjust search setting (model, setting parameter, and the like) RC ■ Influence of random noise during image capturing RB → Reduce influence by employing setting of increasing number of times sampling performed at same position and averaging results RC ■ Variations are large since image is captured before vibration of apparatus ends RB → Inspect time required for vibration to end and adjust imaging timing RC
R5	RA Error of sampling is large even with setting for correction processing	■ Setting for image correction processing is inappropriate RB → Check and adjust setting for image correction processing RC

FIG. 27

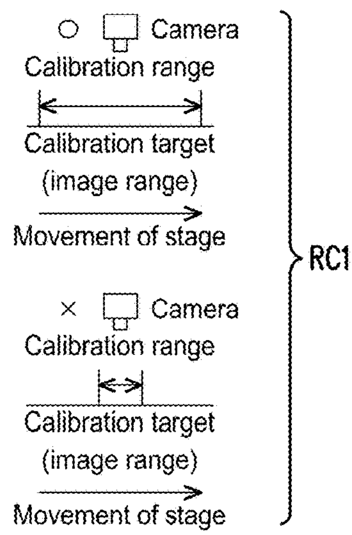
	Evaluation	Estimated factor and countermeasure	
R6	RA Sampling posture (angle) is not constant (linearity)	■ Setting for detecting rotating target is inappropriate (setting for detecting rotating object is employed though object does not rotate, for example) → Adjust search setting related to detection of rotating object	RB RC
R7	RA Calibration has been able to be performed only on part of image (linearity)	■ Setting of calibration (sampling) range is inappropriate and too narrow → Review setting of calibration range and adjust setting 	RB RC

FIG. 28

	Evaluation	Estimated factor and countermeasure	
R8	Variations of sampling are large (rotation center of stage has not accurately been estimated)	■ Setting for detection unit (search or the like) for sampling is inappropriate and unsatisfactory, and sampling has not been able to be constantly performed at same position → Adjust search setting (model, setting parameter, and the like) ■ Influence of random noise during image capturing → Reduce influence by employing setting of increasing number of times sampling performed at same position and averaging results ■ Variations are large since image is captured before vibration of apparatus ends → Inspect time required for vibration to end and adjust imaging timing	RB RC RB RC RB RC
R9	Error of sampling is large even with setting for correction processing	■ Setting for image correction processing is inappropriate → Check and adjust setting for image correction processing	RB RC

FIG. 29

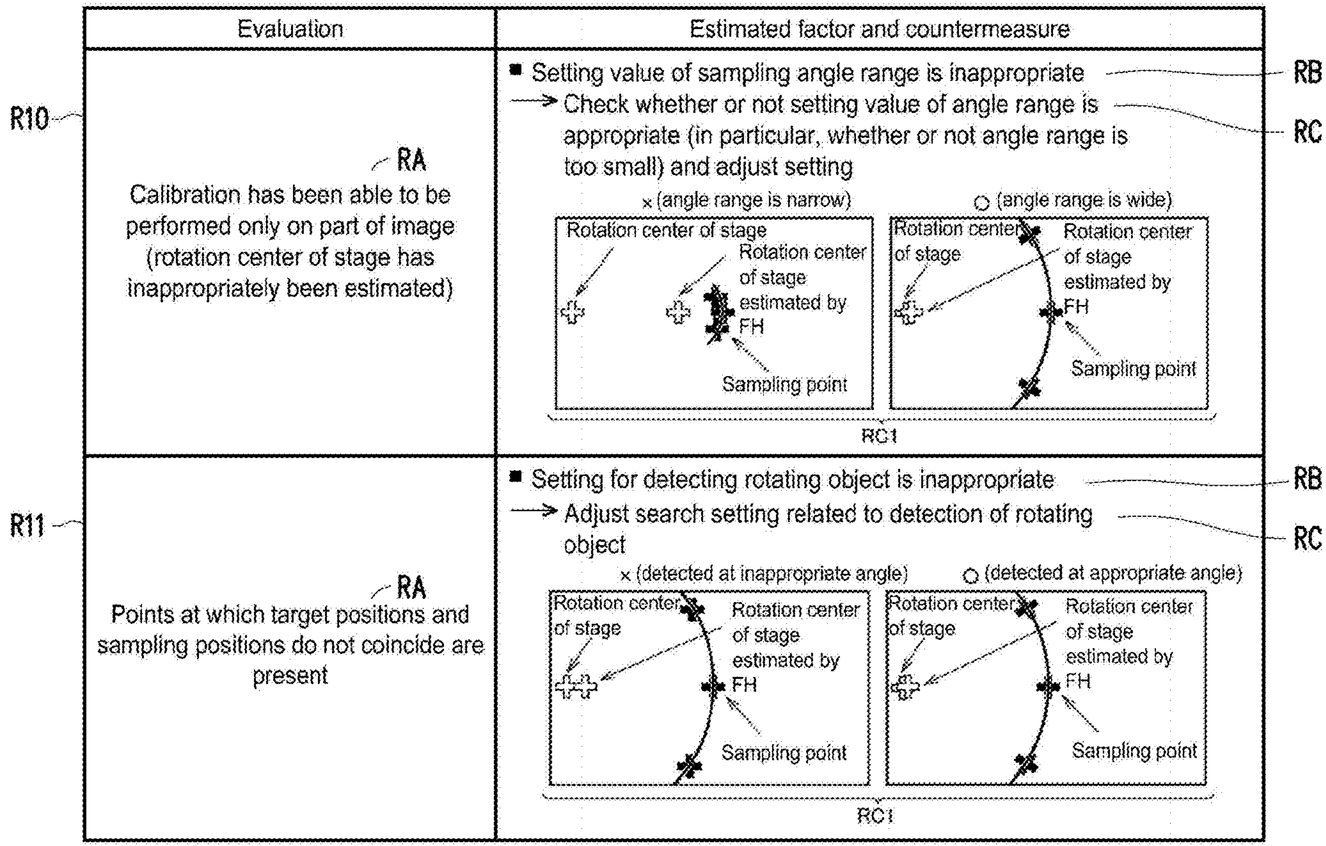

Evaluation
Estimated factor and countermeasure
R10
RA
Calibration has been able to be performed only on part of image (rotation center of stage has inappropriately been estimated)
■ Setting value of sampling angle range is inappropriate
→ Check whether or not setting value of angle range is appropriate (in particular, whether or not angle range is too small) and adjust setting
RB
RC
× (angle range is narrow)
○ (angle range is wide)
Rotation center of stage
Rotation center of stage estimated by FH
Sampling point
RC1
R11
RA
Points at which target positions and sampling positions do not coincide are present
■ Setting for detecting rotating object is inappropriate
→ Adjust search setting related to detection of rotating object
RB
RC
× (detected at inappropriate angle)
○ (detected at appropriate angle)
Rotation center of stage
Rotation center of stage estimated by FH
Sampling point
RC1

FIG. 30

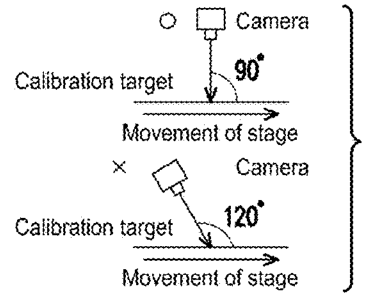
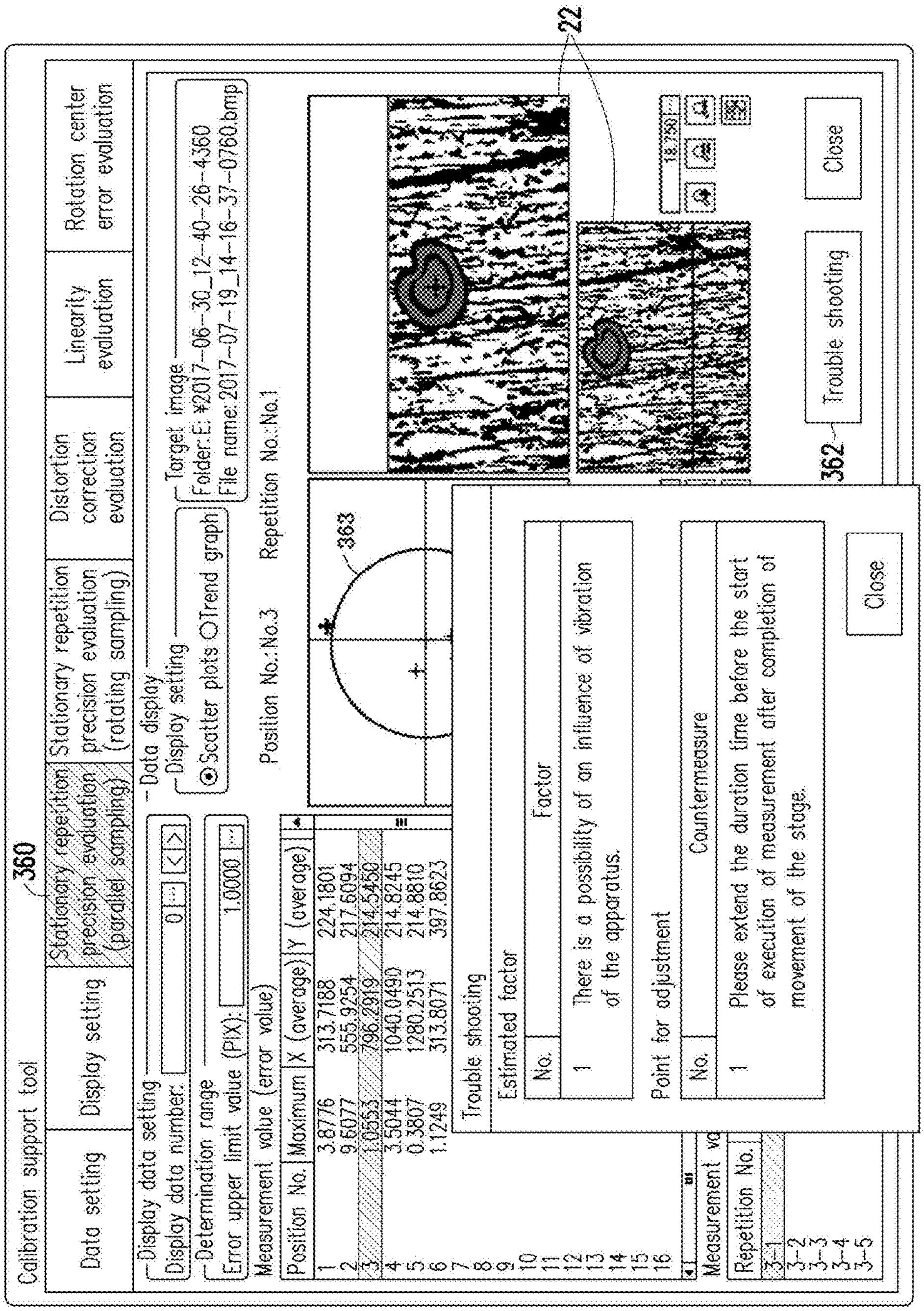
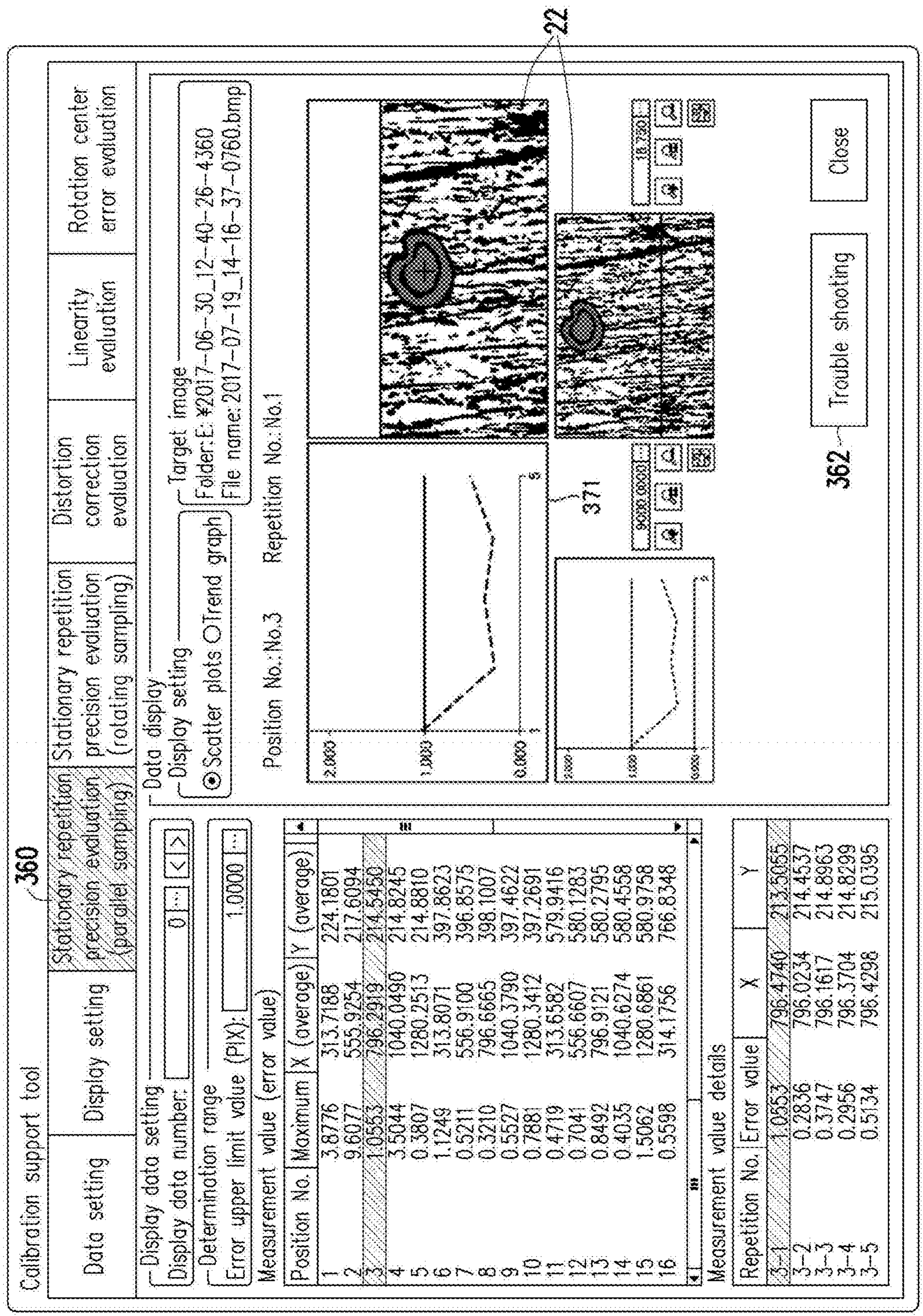
	Evaluation	Estimated factor and countermeasure
R12	RA Sampling intervals are not equal intervals (linearity)	■ Camera has not been installed perpendicularly to calibration target RB → Check and adjust camera installation angle RC  RC1
R13	RA Measurement has not been able to be performed at ideal sampling position	■ There is reason in stage, and inspection related to precision of stage is to be performed ■ Positioning precision is inappropriate RB → Inspect reason of inappropriate positioning precision and adjust stage RC ■ Repeated positioning precision is inappropriate RB → Inspect reason of inappropriate repeated positioning precision and adjust stage RC ■ Lost motion has occurred RB → Inspect reason of large lost motion and adjust stage RC ■ Backlash has occurred RB → Inspect reason of large backlash and adjust stage RB ■ Straightness (horizontal direction) during movement of stage is high RB → Inspect reason of high straightness (horizontal direction) and adjust stage RC ■ Amount of yawing during movement of stage is large RB → Inspect reason of large amount of yawing and adjust stage RC ■ Amount of rolling during movement of stage is large RB → Inspect reason of large amount of rolling and adjust stage RC ■ Amount of pitching during movement of stage is large RB → Inspect reason of large amount of pitching and adjust stage RC ■ Error in XY orthogonality is large RB → Inspect reason of large error in XY orthogonality and adjust stage RC ■ Center runout error of stage is large RB → Inspect reason of large center runout and adjust stage RC ■ Surface runout error of stage is large RB → Inspect reason of large surface runout and adjust stage RC

FIG. 31



Calibration support tool
360
Data setting
Display setting
Stationary repetition precision evaluation (parallel sampling)
Stationary repetition precision evaluation (rotating sampling)
Distortion correction evaluation
Linearity evaluation
Rotation center error evaluation
Display data setting
Display data number:
Determination range
Error upper limit value (PIX):
1.0000
Measurement value (error value)
Position No.
Maximum
X (average)
Y (average)
1 3.8776 313.7188 224.1801
2 9.6077 555.9254 217.6094
3 1.0553 796.2919 214.5450
4 3.5044 1040.0490 214.8245
5 0.3807 1280.2513 214.8810
6 1.1249 313.8071 397.8623
7
8
9
10
11
12
13
14
15
16
Measurement va
Repetition No.
3-1
3-2
3-3
3-4
3-5
Data display
Display setting
Scatter plots
Trend graph
Target image
Folder:E:¥2017-06-30_12-40-26-4360
File name:2017-07-19_14-16-37-0760.bmp
Position No.:No.3
Repetition No.:No.1
363
22
18.750
Trouble shooting
Close
362
Trouble shooting
Estimated factor
No.
Factor
1
There is a possibility of an influence of vibration of the apparatus.
Point for adjustment
No.
Countermeasure
1
Please extend the duration time before the start of execution of measurement after completion of movement of the stage.
Close

FIG. 32



Calibration support tool
360
Data setting
Display setting
Stationary repetition precision evaluation (parallel sampling)
Stationary repetition precision evaluation (rotating sampling)
Distortion correction evaluation
Linearity evaluation
Rotation center error evaluation
Display data setting
Display data number: 0
Determination range
Error upper limit value (PIX): 1.0000
Measurement value (error value)
Position No. Maximum X (average) Y (average)
1 3.8776 313.7188 224.1801
2 9.6077 555.9254 217.6094
3 1.0553 796.2919 214.5450
4 3.5044 1040.0490 214.8245
5 0.3807 1280.2513 214.8810
6 1.1249 313.8071 397.8623
7 0.5211 556.9100 396.8575
8 0.3210 796.6665 398.1007
9 0.5527 1040.3790 397.4622
10 0.7881 1280.3412 397.2691
11 0.4719 313.6582 579.9416
12 0.7041 556.6607 580.1283
13 0.8492 796.9121 580.2795
14 0.4035 1040.6274 580.4558
15 1.5062 1280.6861 580.9758
16 0.5598 314.1756 766.8348
Measurement value details
Repetition No. Error value X Y
3-1 1.0553 796.4740 213.5055
3-2 0.2836 796.0234 214.4537
3-3 0.3747 796.1617 214.8963
3-4 0.2956 796.3704 214.8299
3-5 0.5134 796.4298 215.0395
Data display
Display setting
Scatter plots Trend graph
Position No.:No.3
Repetition No.:No.1
Target image
Folder:E:¥2017-06-30_12-40-26-4360
File name:2017-07-19_14-16-37-0760.bmp
22
371
362
Trouble shooting
Close

FIG. 33

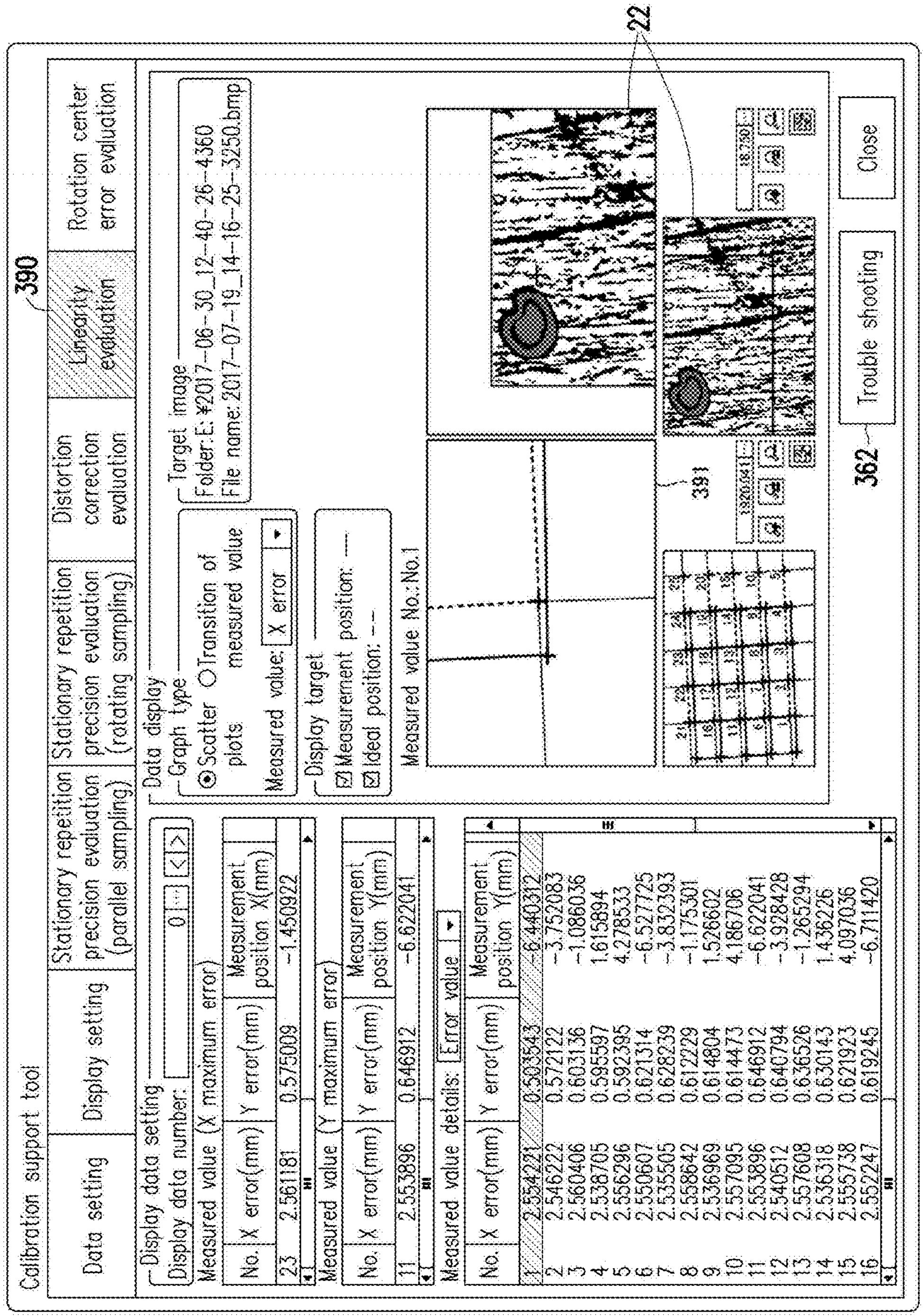

Calibration support tool
Data setting
Display setting
Stationary repetition precision evaluation (parallel sampling)
Stationary repetition precision evaluation (rotating sampling)
Distortion correction evaluation
Linearity evaluation
Rotation center error evaluation
390
Display data setting
Display data number:
Measured value (X maximum error)
No.
X error(mm)
Y error(mm)
Measurement position X(mm)
23
2.561181
0.575009
-1.450922
Measured value (Y maximum error)
Measurement position Y(mm)
11
2.553896
0.646912
-6.622041
Measured value details:
Error value
Data display
Graph type
Scatter plots
Transition of measured value
Measured value:
X error
Display target
Measurement position:
Ideal position:
Measured value No.:No.1
Target image
Folder:E:¥2017-06-30_12-40-26-4360
File name:2017-07-19_14-16-25-3250.bmp
22
391
362
Trouble shooting
Close

FIG. 34

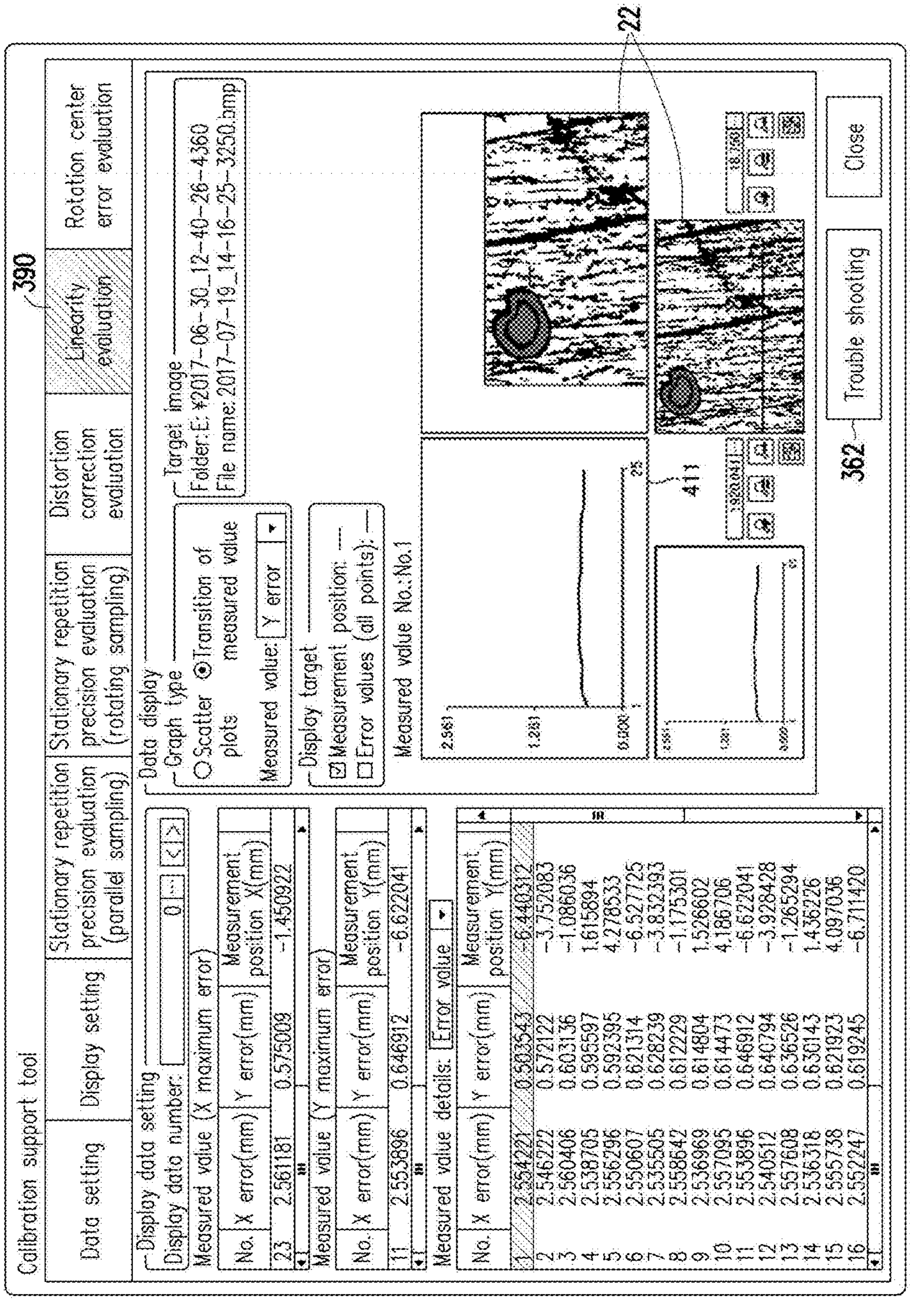

Calibration support tool
Data setting
Display setting
Stationary repetition precision evaluation (parallel sampling)
Stationary repetition precision evaluation (rotating sampling)
Distortion correction evaluation
Linearity evaluation
Rotation center error evaluation
390
Display data setting
Display data number:
Measured value (X maximum error)
No. X error(mm) Y error(mm) Measurement position X(mm)
23 2.561181 0.575009 -1.450922
Measured value (Y maximum error)
No. X error(mm) Y error(mm) Measurement position Y(mm)
11 2.553896 0.646912 -6.622041
Measured value details: Error value
No. X error(mm) Y error(mm) Measurement position Y(mm)
1 2.554221 0.503543 -6.440312
2 2.546222 0.572122 -3.752083
3 2.560406 0.603136 -1.086036
4 2.538705 0.585597 1.615894
5 2.556296 0.592395 4.278533
6 2.550607 0.621314 -6.527725
7 2.535505 0.628239 -3.832593
8 2.558642 0.612229 -1.175301
9 2.536969 0.614804 1.526602
10 2.557095 0.614473 4.186706
11 2.553896 0.646912 -6.622041
12 2.540512 0.640794 -3.928428
13 2.557608 0.636526 -1.265294
14 2.536318 0.636143 1.436226
15 2.555738 0.621923 4.097036
16 2.552247 0.619245 -6.711420
Data display
Graph type
Scatter plots
Transition of measured value
Measured value: Y error
Display target
Measurement position:
Error values (all points):
Measured value No.:No.1
Target image
Folder: E:¥2017-06-30_12-40-26-4360
File name: 2017-07-19_14-16-25-3250.bmp
22
411
362
Trouble shooting
Close

FIG. 35

POSITION DETECTING APPARATUS AND COMPUTER-READABLE RECORDING MEDIUM

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the priority benefit of Japan application serial no. 2017-186021, filed on Sep. 27, 2017. The entirety of the above-mentioned patent application is hereby incorporated by reference herein and made a part of this specification.

BACKGROUND

Technical Field

[0002] The present disclosure relates to a position detecting apparatus and a program for measuring a position of an object, which is moved by a moving mechanism, using image processing and outputting information related to the measured position.

Description of Related Art

[0003] In the field of factory automation (FA), automatic control technologies using visual sensors have been widely used. For example, automated processing of operating various control devices by imaging an object such as a workpiece and executing image measurement processing such as pattern matching on the captured image has been realized.

[0004] In a case in which such visual sensors are used, calibration is needed in order to output results measured by the visual sensors to control devices. For example, Japanese Unexamined Patent Application Publication No. 6-137840 (Patent Document 1) discloses a simple and highly precise calibration method with no restriction of camera arrangement. Also, Japanese Unexamined Patent Application Publication No. 2003-50106 (Patent Document 2) discloses a positioning device based on calibration that does not require an input or adjustment of parameters by an operator.

PATENT DOCUMENTS

[0005] [Patent Document 1] Japanese Laid-open No. 6-137840

[0006] [Patent Document 2] Japanese Laid-open No. 2003-50106

[0007] In a case in which required positioning precision is not satisfied during running or activation of the positioning device, the cause is sought out. However, seeking out the cause requires knowhow of a person skilled in the positioning, and takes time. In addition, a user who has poor knowledge about the positioning does not know where to look. Although the cause of such insufficient positioning precision is insufficient calibration precision in many cases, it is difficult to find the cause. Therefore, it has been desired to shorten the aforementioned time taken to find the cause and to facilitate identification of places to look.

SUMMARY

[0008] The present disclosure is directed to such a need, and one objective thereof is to provide an environment for providing information for supporting adjustment of the respective parts for positioning.

[0009] According to an example of the present disclosure, there is provided a position detecting apparatus including: an image storage portion that stores image data obtained by imaging an object when a feature portion is positioned at a plurality of respective target positions by a moving mechanism configured to change the position of the object in which the feature portion for positioning is provided; an image processing portion that detects a position of the feature portion included in the image data from the image data through image processing; a position storage portion that stores the detected positions detected by the image processing portion in association with the target positions from the image data of the object positioned at the respective target positions; and a display data generation portion that generates data for displaying information related to the detected positions on a display unit. The display data generation portion generates data for displaying the respective target positions and the respective detected positions, which are stored in association with the target positions, in the same coordinate space.

[0010] In the aforementioned disclosure, the object is moved to the respective target positions a plurality of times by the moving mechanism, and the detected positions stored in association with the respective target positions in the position storage portion include a plurality of detected positions detected from the image data imaged and acquired by being moved to the target positions a plurality of times.

[0011] In the aforementioned disclosure, the coordinate space has multidimensional coordinate axes, and the display data generation portion generates data for displaying the target positions and the detected positions associated with the target positions on at least one coordinate axis from among the multidimensional coordinate axes.

[0012] In the aforementioned disclosure, the data for displaying the respective detected positions includes data for displaying the plurality of associated detected positions in a form of scatter plots in the coordinate space for each of the target positions.

[0013] In the aforementioned disclosure, the data for displaying the respective detected positions includes data for displaying the plurality of associated detected positions in a form of a chronological order that follows relative time elapse from a start of the detection of the plurality of detected positions for each of the target positions.

[0014] In the aforementioned disclosure, the data for displaying the respective detected positions includes data for displaying line segments that indicate relative positional relationships between the respective target positions and the detected positions associated with the target positions.

[0015] In the aforementioned disclosure, the line segments that indicate the relative positional relationships include data for displaying a line segment connecting the detected positions associated with the respective target positions in an order of the moving to the target positions by the moving mechanism or data for displaying a line segment connecting the respective target positions in the order of the moving by the moving mechanism.

[0016] In the aforementioned disclosure, the moving includes rotational movement of rotating about a predefined target center position, the target positions include the target center position, and the detected positions include an estimated center position of the rotation, which is estimated from the respective detected positions associated with the respective target positions.

[0017] In the aforementioned disclosure, the data for displaying the respective detected positions includes data for displaying the respective target positions on a circumferential line around the target center position at the center or data for displaying the detected positions associated with the respective target positions on a circumferential line around the estimated center position at the center.

[0018] In the aforementioned disclosure, the data for displaying the respective detected positions includes data for displaying the detected positions with differences from the associated target positions exceeding a threshold value in a predefined form.

[0019] In the aforementioned disclosure, the image processing portion detects an inclination angle from a predefined posture of the feature portion from the image of the feature portion, and the data for displaying the respective detected positions includes data for displaying the detected positions associated with the target positions as a mark that indicates the inclination angle.

[0020] In the aforementioned disclosure, the object is moved to the respective target positions a plurality of times by the moving mechanism, the detected positions stored in association with the respective target positions in the position storage portion include a plurality of detected positions detected from the image data imaged and acquired by being moved to the target positions a plurality of times, and the display data generation portion generates data for displaying statistical values of the plurality of detected positions at the target positions in association with the respective target positions.

[0021] In the aforementioned disclosure, the statistical values include at least a maximum value, a minimum value, and an average value of differences between the plurality of detected positions and the associated target positions.

[0022] In the aforementioned disclosure, the display data generation portion generates data for displaying differences of the plurality of detected positions associated with the target positions from the target positions in a form of a chronological order that follows relative time elapse from a start of the detection of the plurality of detected position.

[0023] In the aforementioned disclosure, the display data generation portion associates differences of the plurality of detected positions associated with the target positions from the target positions with predefined threshold values of the differences and generates data for displaying the respective detected positions in the form of the chronological order that follows the relative time elapse from the start of the detection of the plurality of detected positions.

[0024] In the aforementioned disclosure, the display data generation portion includes a portion that generates data for displaying the image data of the feature portion at which the detected positions are detected.

[0025] In the aforementioned disclosure, the display data generation portion further includes a portion that displays the target positions and the detected positions associated with the target positions in an enlarged manner.

[0026] In the aforementioned disclosure, the image processing includes correction parameters for correcting the image data from an amount of movement of the moving mechanism in order to detect a position of the feature portion from the image data, and the detected positions associated with the target positions include respective detected positions obtained in image processing before and after application of the correction parameters.

[0027] According to an example of the present disclosure, there is provided a position detecting apparatus including: an image storage portion that stores image data obtained by imaging an object when a feature portion is positioned at a plurality of target positions by a moving mechanism configured to change a position of the object in which the feature portion for positioning is provided; an image processing portion that detects a position of the feature portion that is included in the image data from the image data through image processing; a position storage portion that stores the detected positions detected by the image processing portion in association with the target positions from the image data of the object positioned at the respective target positions; a cause storage portion that stores a plurality of predefined cause data items that have evaluation content that represents evaluation of positional differences from the target positions in a coordinate system and an estimated cause estimated for the position differences in linkage with the evaluation content; an evaluation portion that evaluates detection differences that are differences between the target positions and the associated detected positions in the coordinate system in the position storage portion on the basis of a predefined reference; and a display data generation portion that generates data for displaying information related to the evaluation on a display unit. The display generation portion generates data for displaying the estimated cause in the cause storage portion, which corresponds to the evaluation content that represents evaluation by the evaluation portion.

[0028] In the aforementioned disclosure, the cause storage portion stores a countermeasure for addressing the estimated cause in linkage with the estimated cause, and the display data generation portion further generates data for displaying the countermeasure that corresponds to the estimated cause.

[0029] In the aforementioned disclosure, the object is moved to the respective target positions a plurality of times by the moving mechanism, and the detected positions stored in association with the respective target positions in the position storage portion include a plurality of detected positions detected from the image data imaged and acquired by being moved to the target positions a plurality of times.

[0030] In the aforementioned disclosure, the detection differences include statistical values of the differences between the target positions and the plurality of associated detected positions in the position storage portion.

[0031] In the aforementioned disclosure, the statistical values include at least one of values that indicate an average value, a maximum value, a minimum value, and a variation in the differences from the plurality of detected positions.

[0032] In the aforementioned disclosure, the estimated cause can include at least one of a condition for driving the moving mechanism, a parameter for the image processing, and a condition for imaging.

[0033] In the aforementioned disclosure, the display data generation portion generates data for displaying the respective target positions and the respective detected positions stored in association with the target positions in the same coordinate space.

[0034] According to an example of the present disclosure, there is provided a program for causing a computer to execute a position detecting method. The position detecting method includes the steps of: detecting a position of a feature portion that is included in image data from the image data acquired by imaging an object through image processing when the feature portion is positioned at a plurality of respective target positions by a moving mechanism configured to change a position of the object in which the feature portion for positioning is provided; storing the detected positions detected through the image processing in association with the target positions from the image data of the object positioned at the respective target positions; and generating data for displaying information related to the detected positions on a display unit, and the generating of the display data includes generating data for displaying the respective target positions and the respective detected positioned stored in association with the target positions in the same coordinate space.

[0035] According to an example of the present disclosure, there is provided a program for causing a computer to execute a position detecting method. The computer includes: a cause storage unit that stores a plurality of predefined cause data items that have evaluation content that represents evaluation of positional differences from the target positions in a coordinate system and an estimated cause estimated for the positional differences in linkage with the evaluation content. The position detecting method includes the steps of: detecting a position of a feature portion that is included in image data from image data acquired by imaging an object through image processing when the feature portion is positioned at a plurality of respective target positions by a moving mechanism configured to change a position of the object in which the feature portion for positioning is provided; storing the detected positions detected through the image processing in association with the target positions from the image data of the object positioned at the respective target positions; evaluating detection differences that are differences in the coordinate system between the stored target positions and the associated detected positions on a basis of a predefined reference; and generating data for displaying information related to the evaluation on a display unit. The generating of the data for displaying the information includes the step of generating data for displaying an estimated cause. In the generating of the data to be displayed, data for displaying the estimated cause, which corresponds to the evaluation content that represents the evaluation in the evaluating, in the cause storage unit is generated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0036] FIG. **1** a diagram schematically illustrating an example of a scenario in which a position detecting apparatus **100** according to an embodiment is applied.

[0037] FIG. **2** is a diagram illustrating an overall configuration of a position control system **1** according to the embodiment.

[0038] FIG. **3** is a diagram illustrating a hardware configuration of the position detecting apparatus **100** according to the embodiment.

[0039] FIG. **4** is a diagram illustrating a hardware configuration of a motion controller **400** according to the embodiment.

[0040] FIG. **5** is an explanatory diagram of a relationship between a camera coordinate system and an actual coordinate system according to the embodiment.

[0041] FIG. **6** is an explanatory diagram of a relationship between the camera coordinate system and the actual coordinate system according to the embodiment.

[0042] FIG. **7** is an explanatory diagram of a relationship between the camera coordinate system and the actual coordinate system according to the embodiment.

[0043] FIG. **8** is an explanatory diagram of a relationship between the camera coordinate system and the actual coordinate system according to the embodiment.

[0044] FIG. **9** is an explanatory diagram of a relationship between the camera coordinate system and the actual coordinate system according to the embodiment.

[0045] FIG. **10** is an explanatory diagram of a relationship between the camera coordinate system and the actual coordinate system according to the embodiment.

[0046] FIG. **11** is an explanatory diagram of a relationship between the camera coordinate system and the actual coordinate system according to the embodiment.

[0047] FIG. **12** is an explanatory diagram of a relationship between the camera coordinate system and the actual coordinate system according to the embodiment.

[0048] FIG. **13** is an explanatory flowchart illustrating calibration processing in association with positioning processing when executed, according to the embodiment.

[0049] FIG. **14** is an explanatory flowchart illustrating the calibration processing in FIG. **13** in association with other processing.

[0050] FIG. **15**A, FIG. **15**B, FIG. **15**C and FIG. **15**D are diagrams illustrating an example of a position associating screen according to the embodiment.

[0051] FIG. **16** is a diagram illustrating an example of the position associating screen according to the embodiment.

[0052] FIG. **17** is a diagram illustrating an example of the position associating screen according to the embodiment.

[0053] FIG. **18** is a diagram illustrating an example of the position associating screen that displays variations in sampling positions according to the embodiment.

[0054] FIG. **19** is a diagram illustrating an example of the position associating screen that displays variations in the sampling positions according to the embodiment.

[0055] FIG. **20** is a diagram illustrating an example of the position associating screen that displays an effect of distortion correction according to the embodiment.

[0056] FIG. **21** is a diagram illustrating an example of the position associating screen obtained by sampling based on linear movement according to the embodiment.

[0057] FIG. **22** is a diagram illustrating an example of the position associating screen obtained by sampling based on rotation movement according to the embodiment.

[0058] FIG. **23** is a diagram illustrating another example of the position associating screen obtained by sampling based on rotation movement according to the embodiment.

[0059] FIG. **24** is a diagram illustrating another example of the position associating screen obtained by sampling based on rotation movement according to the embodiment.

[0060] FIG. **25** is a diagram illustrating another example of the position associating screen obtained by sampling based on rotation movement according to the embodiment.

[0061] FIG. **26** is a diagram illustrating an example of cause data Ri according to the embodiment.

[0062] FIG. **27** is a diagram illustrating an example of the cause data Ri according to the embodiment.

[0063] FIG. **28** is a diagram illustrating an example of the cause data Ri according to the embodiment.

[0064] FIG. **29** is a diagram illustrating an example of the cause data Ri according to the embodiment.

[0065] FIG. **30** is a diagram illustrating an example of the cause data Ri according to the embodiment.

[0066] FIG. **31** is a diagram illustrating an example of the cause data Ri according to the embodiment.

[0067] FIG. **32** is a diagram exemplifying a user interface (UI) screen that is displayed during calibration according to the embodiment of the present disclosure.

[0068] FIG. **33** is a diagram exemplifying the UI screen that is displayed during the calibration according to the embodiment of the present disclosure.

[0069] FIG. **34** is a diagram exemplifying the UI screen that is displayed during the calibration according to the embodiment of the present disclosure.

[0070] FIG. **35** is a diagram exemplifying the UI screen that is displayed during the calibration according to the embodiment of the present disclosure.

DESCRIPTION OF THE EMBODIMENTS

[0071] According to the disclosure, it is possible to display the detected position of the feature portion, which is detected from the image data acquired by imaging the object moved to the respective target positions while the feature portion for the positioning that the object has is positioned at the plurality of target positions by the moving mechanism, in association with the target positions in the same coordinate space. Such display information can be provided as support information for improving calibration precision in a case of performing the calibration by using the position detecting apparatus.

[0072] According to the disclosure, it is possible to display the plurality of detected positions that are detected by being moved to the respective target positions a plurality of times in association with the target positions in the same coordinate space.

[0073] According to the disclosure, it is possible to display the respective target positions and the detected positions associated with the target positions in association in the coordinate space defined by at least one or more coordinate axes.

[0074] According to the disclosure, it is possible to cause the detected positions associated with the respective target positions to be displayed in the form of scattered plots that indicate a variation.

[0075] According to the disclosure, it is possible to cause the plurality of detected positions associated with the respective target positions to be displayed in the form of the chronological order that follows the relative time elapse from the start of the detection of the plurality of detected positions.

[0076] According to the disclosure, it is possible to cause the respective target positions and the detected positions associated with the target positions by line segments that indicate the relative positional relationships therebetween.

[0077] According to the disclosure, it is possible to cause the relative positional relationship between the respective target positions and the detected positions associated with the target positions to be displayed by the line segments connecting the detected positions in the order of the moving to the target positions by the moving mechanism or the line segments connecting the respective target positions in the order of the moving by the moving mechanism.

[0078] According to the disclosure, it is possible to cause the target center position that is the center of the rotation movement and the estimated center position of the rotation estimated from the detected positions associated with the target positions to be displayed in the associated manner in the same coordinate space in a case in which the rotation movement is performed by the moving mechanism.

[0079] According to the disclosure, it is possible to cause the respective target positions to be displayed on the circumferential line around the target center position as the center and to cause the detected positions associated with the respective target positions to be displayed on the circumferential line around the estimated center position as the center in a case in which the rotation movement is performed by the moving mechanism.

[0080] According to the disclosure, it is possible to cause the detected positions with the differences from the target positions exceeding the threshold value from among the detected positions associated with the target positions to be displayed in the predefined form.

[0081] According to the disclosure, it is possible to cause the image of the feature portion at the detected positions to be displayed by the mark that indicates the inclination angle from the predefined posture.

[0082] According to the disclosure, it is possible to cause the statistical values acquired from the plurality of detected positions associated with the respective target positions to be displayed.

[0083] According to the disclosure, it is possible to cause one of the maximum value, the minimum value, and the average value of the differences between the detected positions and the associated target positions to be displayed as statistical values acquired from the plurality of detected positions associated with the respective target positions.

[0084] According to the disclosure, it is possible to cause the differences of the plurality of detected positions associated with the target positions from the target positions to be displayed in the form of the chronological order that follows the relative time elapse from the start of the detection of the plurality of detected positions.

[0085] According to the disclosure, it is possible to cause the differences of the plurality of respective detected positions associated with the target positions from the target positions to be displayed in association with the predefined threshold values of the differences in the form of the chronological order that follows the relative time elapse from the start of the detection of the plurality of detected positions.

[0086] According to the disclosure, it is possible to display the image of the feature portion detected at the detected positions.

[0087] According to the disclosure, it is possible to cause the target positions and the detected positions associated with the target positions to be displayed in the enlarged manner.

[0088] According to the disclosure, it is possible to cause the detected positions before the correction parameters for correcting the image data from the amount of movement of the moving mechanism is applied and the detected positions detected by applying the correction parameters to be displayed as the detected positions associated with the target positions.

[0089] According to the disclosure, it is possible to evaluate the position differences between the detected position of the feature portion detected from the image data acquired by imaging the object that has moved to the respective target positions and to cause the cause associated in advance with the evaluation content and estimated to lead to the position differences to be displayed in a case in which the feature points for the positioning that the object has are moved while being positioned at the plurality of respective target positions.

[0090] According to the disclosure, it is possible to cause the aforementioned estimated cause and the countermeasure for addressing the cause to be displayed.

[0091] According to the disclosure, it is possible to use the plurality of detected positions detected by being moved to the target positions a plurality of times as the detected positions associated with the respective target positions.

[0092] According to the disclosure, it is possible to use the aforementioned statistical values as the detection differences.

[0093] According to the disclosure, it is possible to use at least one of the average value, the maximum value, the minimum value, and the variation of the differences from the plurality of respective detected positions as the statistical values of the detection differences.

[0094] According to the disclosure, it is possible to display at least one of the condition for driving the moving mechanism, the parameter for the image processing, and the condition for imaging.

[0095] According to the disclosure, it is possible to cause the detected position of the feature portion detected from the image data acquired by imaging the object that has moved to the respective target positions to be displayed in association with the target positions in the same coordinate space in a case in which the object is moved by the moving mechanism while the feature portion for positioning is positioned at the plurality of respective target positions.

[0096] According to the present disclosure, it is possible to cause the detected portions of the feature portion detected from the image data acquired by imaging the object that has moved to the respective target positions to be displayed in association with the target positions in the same coordinate space in a case in which the object is moved by the moving mechanism while the feature portion for positioning is positioned at the plurality of respective target positions if the program is executed.

[0097] According to an example of the present disclosure, it is possible to provide an environment which provides information for supporting adjustment of the respective parts for positioning.

[0098] An embodiment of the present disclosure will be described in detail with reference to the drawings. Note that the same reference numerals will be applied to the same or corresponding parts in the drawings and description thereof will not be repeated;

A. APPLICATION EXAMPLE

[0099] First, an example of a scenario to which the present disclosure is applied will be described with reference to FIG. **1**. FIG. **1** is a diagram schematically illustrating an example of a scenario to which a position detecting apparatus **100** according to an embodiment is applied. Calibration, for example, is performed in the position detecting apparatus **100** according to the embodiment. The calibration is performed when the position detecting apparatus **100** is actually operated for alignment, for example.

[0100] In the calibration, the position of an arbitrary object that is moved by a moving mechanism (for example, a servo motor **300**, which will be described later, or the like) is detected. The position detecting apparatus **100** can be assembled in a visual sensor, for example. The moving mechanism can include various actuators such as a servo motor **300**, which will be described later, for example. The object can include a workpiece or the like that can be a target of an inspection using image processing performed by the visual sensor during the actual operation, for example.

[0101] As illustrated in FIG. **1**, the position detecting apparatus **100** includes an image storage unit **60** that stores image data **10** acquired by imaging the object when the feature portion is positioned at a plurality of respective target positions **21** by the moving mechanism configured to change the position of the object in which a feature portion (for example, a mark **14**, which will be described later, or the like) for positioning is provided, an image processing unit **50**, a position storage unit **80**, and a display data generation unit **85**. The aforementioned feature portion for positioning is more typically a target mark of the calibration, and a dedicated target mark for the calibration or the like may be used. Alternatively, a feature portion for a positioning operation may be used.

[0102] The image processing unit **50** detects the positions of the feature portion that is included in the image data **10** from the captured image data **10** through image processing. The position storage unit **80** stores the detected positions (that is, sampling positions **20**) detected from the image data **10** of the object positioned at the respective target positions **21** through the aforementioned image processing in association with the target positions **21**. The display data generation unit **85** generates data for displaying the respective target positions **21** and the respective detected positions (sampling positions **20**) stored in association with the target positions **21** in the same coordinate space on a display unit. The aforementioned coordinate space on the display unit can include a two-dimensional coordinate space of multidimensional axes, for example, an X axis and a Y axis, or a coordinate space of a one-dimensional axis, namely, an X axis (Y axis).

[0103] In addition, a command unit **95** controls the moving mechanism such that the feature portion of the object is positioned at the respective target positions **21** by providing a control command **96** to the moving mechanism (for example, the servo motor **300** or the like) by using the plurality of target positions **21**. The control command **96** can correspond to a control command (for example, a drive pulse or the like) to the servo motor **300**, for example. The image acquisition unit **40** acquires the image data **10** imaged by a camera **104** via an image buffer **122*a***, which will be described later, in synchronization with an output of the control command **96**. In this manner, the position detecting apparatus **100** can acquire the image data **10** imaged by the camera **104** every time the object moves to the respective target positions **21**.

[0104] In the position detecting apparatus **100** according to the embodiment, the target positions **21** and the detected position of the feature portion detected in a case in which the object is moved by the moving mechanism such that the feature portion is positioned at the target positions can be acquired and can be displayed in the same coordinate space in the associated manner. In this manner, it is possible to present relative positional relationships between the respective target positions **21** and the detected positions (sampling positions **20**), which have been detected through the image processing, of the feature portion moved to be positioned at the respective target positions to a user. The positional relationships can include errors of the detected positions from the target positions **21**. Therefore, the position detecting apparatus **100** can provide the presented positional relationships as information for supporting adjustment in a case in which the user adjusts setting or imaging conditions (illumination, an imaging posture (angle), and the like) for the moving mechanism or the image processing, for example.

[0105] In addition, the position detecting apparatus **100** according to the embodiment includes a cause storage unit **90** that stores a plurality of predefined cause data items Ri (i=1, 2, 3, . . .) that have evaluation content RA that represents evaluation of the positional differences that are differences from the target positions **21** in the coordinate system and an estimated cause RB estimated for the positional differences in linkage with the evaluation content, and an evaluation unit **70** that evaluates differences between the target positions **21** and the associated detected positions in the coordinate system in the position storage unit **80** with a predefined reference (corresponding to reference data **35**). In the embodiment, the aforementioned coordinate system is an actual coordinate system (unit: mm) obtained by transforming a camera coordinate system (unit: pix (pixels)) obtained by imaging by using a function (affine transformation, distortion correction, or the like), for example. In addition, the amount (unit: mm) of movement of the moving mechanism, for example, can be expressed by the amount of movement in the actual coordinate system in the embodiment. The display data generation unit **85** generates data for displaying, on the display unit, the estimated cause RB, which corresponds to the evaluation content RA that represents the evaluation by the evaluation unit **70**, in the cause storage unit **90**.

[0106] Although the image storage unit **60**, the position storage unit **80**, and the cause storage unit **90** correspond to, for example, a storage region such as a RAM **112** in FIG. **3**, which will be described later, in the embodiment, the image storage unit **60**, the position storage unit **80**, and the cause storage unit **90** are not limited to the RAM **112**.

[0107] The position detecting apparatus **100** according to the embodiment can evaluate the differences of the detected positions (sampling positions **20**) from the target positions **21** with a predefined reference as errors in the detection. The evaluation result can be displayed as a cause estimated to cause the errors on the display unit. In the embodiment, the estimated cause can include a condition for driving the moving mechanism, a parameter for image processing, a condition for imaging, or the like. In this manner, the position detecting apparatus **100** can provide the estimated cause to be displayed as information for supporting adjustment of the setting of the correction parameter, the imaging condition, or the like for the moving mechanism or the image processing, for example, by the user.

[0108] Hereinafter, a more detailed configuration and processing of the position detecting apparatus **100** according to the embodiment will be described as a more specific application example of the present disclosure.

B. OVERALL CONFIGURATION EXAMPLE OF POSITION CONTROL SYSTEM

[0109] FIG. **2** is a diagram illustrating an overall configuration of the position control system **1** according to the embodiment. Referring to FIG. **2**, the position control system **1** performs alignment by using image processing when the position control system **1** is actually operated in a production line of industrial products or the like. The alignment typically means processing of arranging workpieces at original positions on the production line. A workpiece **4** has a feature portion for positioning. In an example of such alignment, the position control system **1** specifies a feature image that is a partial image corresponding to the feature portion from image data obtained by imaging an object (workpiece **4**) arranged on an upper surface of a stage **2**, detects the position of the specified feature image, and arranges (positions) the workpiece **4** at an accurate position by controlling the stage **2** on the basis of the detected position data (position coordinates in the embodiment).

[0110] As illustrated in FIG. **2**, the position control system **1** includes the position detecting apparatus **100**, a motion controller **400**, and the stage **2**. The position detecting apparatus **100** acquires image data imaged by the camera **104** and detects the position of the mark **14** for positioning that is included in the acquired image data, thereby specifying the position of the feature portion in the workpiece **4**. The camera **104** can include a charge coupled device (CCD) camera, for example. The position detecting apparatus **100** outputs a command for arranging the workpiece **4** at an accurate position on the basis of the specified positions to the motion controller **400**.

[0111] The motion controller **400** provides a command to the stage **2** in accordance with the control command **96** from the position detecting apparatus **100**, thereby realizing alignment of the workpiece **4**.

[0112] The stage **2** may have any degree of freedom as long as the stage **2** is a mechanism capable of arranging the workpiece **4** at the accurate position. In the embodiment, the stage **2** can provide displacement in the horizontal direction and displacement of rotation, for example, to the workpiece **4**.

C. OVERALL CONFIGURATION OF POSITION DETECTING APPARATUS

[0113] FIG. **3** is a diagram illustrating a hardware configuration of the position detecting apparatus **100** according to the embodiment. As illustrated in FIG. **3**, the position detecting apparatus **100** typically has a structure that is compatible with a general-purpose computer architecture and realizes various kinds of processing as will be described later by a processor executing a program installed in advance.

[0114] More specifically, the position detecting apparatus **100** includes a processor **110** such as a central processing unit (CPU) or a micro-processing unit (MPU), a random access memory (RAM) **112**, a display controller **114**, a system controller **116**, an input/output (I/O) controller **118**, a hard disk **120**, a camera interface **122**, an input interface **124**, a motion controller interface **126**, a communication interface **128**, and a memory card interface **130**. These respective parts are connected around the system controller **116** at the center such that the respective parts can communicate with each other.

[0115] The processor **110** exchanges programs (codes) or the like with the system controller **116** and executes them in a predetermined order, thereby realizing target arithmetic processing.

[0116] The system controller **116** is connected to the processor **110**, the RAM **112**, the display controller **114**, and the I/O controller **118** via a bus, exchanges data and the like with the respective parts, and manages the entire processing performed by the position detecting apparatus **100**.

[0117] The RAM **112** is typically a volatile storage device such as a dynamic random access memory (DRAM) and holds programs read from the hard disk **120**, camera images (image data) acquired by the camera **104**, data (manually input coordinates and the like) related to the image data, workpiece data, and the like.

[0118] The display controller **114** is connected to a display unit **132** and outputs a signal for displaying various kinds of information to the display unit **132** in accordance with an internal command, such as display data, from the system controller **116**.

[0119] The I/O controller **118** controls exchange of data with a recording medium or an external device connected to the position detecting apparatus **100**. More specifically, the I/O controller **118** is connected to the hard disk **120**, the camera interface **122**, the input interface **124**, the motion controller interface **126**, the communication interface **128**, and the memory card interface **130**.

[0120] The hard disk **120** is typically a non-volatile magnetic storage device, and various setting values and the like are stored therein in addition to the control program **150** such as algorithms executed by the processor **110**. The control program **150** installed in the hard disk **120** is distributed in a state in which the control program **150** is stored in a memory card **136** or the like. Note that a semiconductor storage device such as a flash memory or an optical storage device such as a digital versatile disk random access memory (DVD-RAM) may be employed instead of the hard disk **120**.

[0121] The camera interface **122** acquires the image data obtained by imaging the workpiece and relays data transfer between the processor **110** and the camera **104**. The camera interface **122** includes an image buffer **122***a* for temporarily accumulating the image data from the camera **104**.

[0122] The input interface **124** relays data transfer between the processor **110** and an input device such as a keyboard **134**, a mouse **138**, a touch panel, or a dedicated console.

[0123] The motion controller interface **126** relays data transfer between the processor **110** and the motion controller **400**.

[0124] The communication interface **128** relays data transfer between the processor **110** and another personal computer, a server device, or the like, which are not illustrated in the drawing. The communication interface **128** is typically Ethernet (registered trademark), a universal serial bus (USB), or the like.

[0125] The memory card interface **130** relays data transfer between the processor **110** and the memory card **136** that is a recording medium. The memory card **136** is distributed in a state in which the control program or the like to be executed by the position detecting apparatus **100** is stored, and the memory card interface **130** reads the control program **150** from the memory card **136**. The memory card **136** is a general-purposed semiconductor storage device such as a secure digital (SD), a magnetic recording medium such as a flexible disk, an optical recording medium such as a compact disk read only memory (CD-ROM), or the like. Alternatively, a program downloaded from a distribution server or the like may be installed in the position detecting apparatus **100** via the communication interface **128**.

[0126] In a case in which a computer that has a structure compatible with the aforementioned computer architecture is used, an operating system (OS) for providing basic functions of a computer may be installed in addition to an application for providing the functions according to the embodiment. In this case, the control program according to the embodiment may be a program for executing processing by calling necessary modules from among program modules provided as a part of the OS in a predetermined order and/or a predetermined timing.

[0127] Further, the control program **150** according to the embodiment may be provided by being assembled as a part of another program. The program itself does not include modules included in another program to be combined as described above, and the processing is executed in cooperation with another program even in that case. That is, the control program **150** according to the embodiment may be in a form in which the control program **150** is assembled in such another program.

[0128] Note that a part or entirety of the functions provided by executing the control program **150** may be mounted on a dedicated hardware circuit such as an application specific integrated circuit (ASIC) or a field-programmable gate array (FPGA) instead.

D. OVERALL CONFIGURATION OF MOTION CONTROLLER

[0129] FIG. **4** is a diagram illustrating a hardware configuration of the motion controller **400** according to the embodiment. As illustrated in FIG. **4**, the motion controller **400** includes a main control unit **210** and a plurality of servo units **240**, **242**, and **244**. An example in which the stage **2** has servo motors **310**, **312**, and **314** corresponding to three axes is illustrated, and the servo units **240**, **242**, and **244**, the number of which corresponds to the number of axes, are included in the motion controller **400** in the position control system **1** according to the embodiment. In a case in which the servo motors **310**, **312**, and **314** are not particularly distinguished, the servo motors **310**, **312**, and **314** will be collectively referred to as servo motors **300** in the embodiment.

[0130] The main control unit **210** manages overall control of the motion controller **400**. The main control unit **210** is connected to the servo units **240**, **242**, and **244** via an internal bus **226** and exchanges data with each other. The servo units **240**, **242**, and **244** output control commands (typically, drive pulses and the like) to servo drivers **250**, **252**, and **254**, respectively, in accordance with an internal command or the like from the main control unit **210**. The servo drivers **250**, **252**, and **254** drive the servo motors **310**, **312**, and **314** connected thereto, respectively.

[0131] The main control unit **210** includes a chip set **212**, a processor **214**, a non-volatile memory **216**, a main memory **218**, a system clock **220**, a memory card interface **222**, a communication interface **228**, and an internal bus controller **230**. The chip set **212** and other components are linked to each other via various buses.

[0132] The processor **214** and the chip set **212** typically have configurations that are compatible with a general-purposed computer architecture. That is, the processor **214** interprets and executes order codes that are sequentially supplied from the chip set **212** in accordance with an internal clock. The chip set **212** exchanges internal data with various components connected thereto and generates order codes necessary for the processor **214**. The system clock **220** generates a system clock of a predefined cycle and supplies the system clock to the processor **214**. The chip set **212** has a function of caching data and the like obtained as a result of executing arithmetic processing by the processor **214**.

[0133] The main control unit **210** has the non-volatile memory **216** and the main memory **218**. The non-volatile memory **216** holds an OS, a system program, a user program, data definition information, log information, and the like in a non-volatile manner. The main memory **218** is a volatile storage display region, holds various programs to be executed by the processor **214**, and is also used as a working memory during execution of the various programs.

[0134] The main control unit **210** has the communication interface **228** and the internal bus controller **230** as communication portions. These communication circuits transmit and receive data.

[0135] The communication interface **228** exchanges data with the position detecting apparatus **100**. The internal bus controller **230** controls the exchange of data via the internal bus **226**. More specifically, the internal bus controller **230** includes a buffer memory **236** and a dynamic memory access (DMA) control circuit **232**.

[0136] The memory card interface **222** connects a detachable memory card **224** and the chip set **212** to the main control unit **210**.

E. RELATIONSHIP BETWEEN CAMERA COORDINATE SYSTEM AND ACTUAL COORDINATE SYSTEM

[0137] FIGS. **5** to **12** are explanatory diagrams of a relationship between the camera coordinate system and an actual coordinate system according to the embodiment. In the embodiment, processing of transforming the camera coordinate system (unit: pix pixels) that is a two-dimensional coordinate system that is defined by image data imaged by the camera **104** in the field of view of the camera in FIG. **5** into an actual coordinate system is performed.

[0138] In the embodiment, the actual coordinate system is an XY two-dimensional coordinate system (unit: mm) in which the stage **2** (or the workpiece **4**) moves with the amount of movement (the moving direction, the distance, and the like) changed due to the amount of rotation (the rotation direction, the rotation angle, and the like) of the servo motors **300** that are moving mechanisms. Note that although the actual coordinate system and the camera coordinate system are virtual coordinate spaces defined by two-dimensional coordinate axes (XY axes) in the embodiment, the actual coordinate system and the camera coordinate system may be coordinate spaces defined by multidimensional coordinate axes (XYZ axes and the like) of three or more dimensions. In calibration according to the embodiment, detecting the position of the object by the image processing unit **50** from the image data imaged and acquired is also referred to as "sampling", and the detected positions (unit: pix) are also referred to as "sampling points".

[0139] First, the camera coordinate system of parallel movement will be described. If the servo motors **310**, **312**, and **314** are driven by an internal command from the main control unit **210**, and the stage **2** is moved in the X direction in parallel by the predefined amount (unit: mm) of movement of the stage in a state in which a mark TM is arranged at a reference position on the stage **2** as illustrated in FIG. **6**, the position of the mark TM in the camera coordinate system moves from the reference position (X1, Y1) to the position (X2, Y2) (see FIG. **7**).

[0140] Similarly, if the stage **2** is caused to be moved in parallel in the Y direction by the predefined amount (unit: mm) of movement of the stage, the mark TM in the camera coordinate system moves from the reference position (X1, Y1) to the position (X3, Y3) (see FIG. **8**). In this manner, the camera coordinate system (see FIG. **9**) of the parallel movement is generated.

[0141] Next, the camera coordinate system of rotation movement as illustrated in FIGS. **10** and **11** will be described. First, if the servo motors **310**, **312**, and **314** are driven by an internal command from the main control unit **210**, and the stage **2** is rotationally moved in a horizontal plane by a predefined amount of movement (angles $\theta 1$ and $\theta 2$) in a state in which the mark TM is arranged at the reference position on the stage **2** as illustrated in FIG. **10**, the mark TM in the camera coordinate system moves from the reference position (X1, Y1) to the position (XR1, YR1) and then to the position (XR2, YR2) (see FIG. **10**).

[0142] The image processing unit **50** calculates coordinates of a rotation center C of the camera coordinate system from the angles $\theta 1$ and $\theta 2$ and the positions (X1, Y1), (XR1, YR1), and (XR2, YR2). The image processing unit **50** moves an origin of the camera coordinate system to the aforementioned rotation center C. In this manner, the camera coordinate system of the rotation movement in FIG. **11** in consideration of the rotation center is generated.

[0143] The relationship between the camera coordinate system and the actual coordinate system according to the embodiment is schematically illustrated in FIG. **12**. In a case in which the stage **2** (or the workpiece **4**) is moved in parallel by the moving mechanism, the image processing unit **50** detects the position (unit: pix) of the mark **14** in the camera coordinate system in FIG. **9** and transforms the detected position into the position (unit: mm) in the actual coordinate system in FIG. **12**. In this manner, the sampling position (unit: mm) of the mark **14** in the actual coordinate system is detected, and it becomes possible to compare the sampling position (unit: mm) with the target position (unit: mm) of the mark **14** in the actual coordinate system.

[0144] In addition, in a case in which the stage **2** (or the workpiece **4**) is rotationally moved by the moving mechanism, the image processing unit **50** detects the position (unit: pix) of the mark **14** in the camera coordinate system in FIG. **11** and transforms the detected position into the position (unit: mm) in the actual coordinate system in FIG. **12**. In this manner, the sampling position (unit: mm) of the mark **14** in the actual coordinate system is detected, and it becomes possible to compare the sampling position (unit: mm) with the target position (unit: mm) of the mark **14** in the actual coordinate system.

[0145] In the embodiment, the image processing unit **50** uses predefined function, for example, a function for correcting various kinds of distortion such as affine transformation, trapezoidal distortion correction, and lens distortion correction for mapping (that is, correcting) the camera coordinate system in the actual coordinate system in order to transform the camera coordinate system into the actual coordinate system as described in FIGS. **5** to **12**. Note that the correction function to be applied to the transformation is not limited thereto.

[0146] FIG. **12** illustrates an example of a parameter table **121** according to the embodiment. A parameter table **121**

includes parameters used for the aforementioned correction function. The parameter table **121** can be displayed on the display unit **132** and can switch a parameter setting pattern by changing values of the parameter in the parameter table **121** through a user's operation of the keyboard **134** or the like. The image processing unit **50** calculates the sampling position in accordance with the parameter setting pattern and the aforementioned function. In this manner, it is possible to cause precision in detecting the sampling position to be improved by changing the setting pattern.

F. CALIBRATION PROCESSING AND PROCESSING DURING OPERATION

[0147] FIG. **13** is an explanatory outline flowchart of calibration processing and positioning processing during operations including the calibration according to the embodiment. FIG. **14** is an explanatory flowchart illustrating the calibration processing in FIG. **13** in association with other processing. Referring to FIG. **13**, if the calibration processing (Steps T**1** and T**2**) according to the embodiment is performed, and the calibration is completed, the position control system **1** is actually operated.

[0148] In addition, the calibration may be performed in processing (Steps T**3** and T**5**) for the actual operations. A program that follows the flowchart in FIG. **13** or **14** can be included in the control program **150**.

[0149] (F-1. Calibration Processing)

[0150] FIG. **14** illustrates the calibration processing along with other processing (evaluation processing (Step S**9**), cause analysis and output processing (Step S**15**), and adjustment processing (S**17**)) related to the calibration. In the calibration processing in FIG. **14**, the sampling is performed at the respective target positions **21** while the workpiece **4** that has the mark **14** as the feature amount is imaged by the camera **104** as illustrated in FIG. **5** and the mark **14** of the workpiece **4** is moved to the predefined plurality of respective target positions **21** in the actual coordinate system by the moving mechanism.

[0151] Specifically, the workpiece **4** is imaged by the camera **104** (Step S**1**) when the workpiece is moved to the target position **21** by the moving mechanism, the image acquisition unit **40** acquires the image data **10** imaged and obtained, the image processing unit **50** specifies the feature portion (mark **14**) from the acquired image data **10** through image processing such as pattern matching, detects the position of the specified feature portion in the camera coordinate system, and transforms the detected position into the sampling position **20** in the actual coordinate system in accordance with the aforementioned mapping function and the parameter setting pattern (Step S**3**). In addition, the position detecting apparatus **100** stores the sampling position **20** in association with the corresponding target position **21** and the feature image **22** of the specified feature portion (mark **14**) in the position storage unit **80**, and stores the image data **10** in association with the sampling position **20** in the image storage unit **60**. In this manner, the imaged image data **10**, the feature image **22** specified from the image data **10**, the sampling position **20**, and the corresponding target position **21** are mutually stored in association every time the workpiece **4** moves to the target position **21**.

[0152] The position detecting apparatus **100** determines whether or not a predefined plurality of samplings for the calibration have been performed (Step S**5**). If it is determined that the predefined plurality of samplings have not ended, ("COLLECTION NOT ENDED" in Step S**5**), the position detecting apparatus **100** calculates the amount of control, such as the amount of movement of the stage **2** to the next target position **21** (Step S**13**), and outputs a moving command including the calculated amount of movement to the motion controller **400** (Step S**14**). In the motion controller **400**, the moving mechanism is driven by the control command in accordance with the moving command, and the workpiece **4** moves to the next target position **21**. Thereafter, the processing returns to Step S**1**, and the processing in and after Step S**3** is performed.

[0153] Meanwhile, if the position detecting apparatus **100** determines that the predefined plurality of samplings have ended ("COLLECTION ENDED" in Step S**5**), the evaluation unit **70** performs evaluation processing of evaluating the sampling position **20** stored in association with the target position **21** in the position storage unit **80** by using reference data **35** (Step S**9**). The evaluation processing is processing of evaluating whether or not the calibration has reasonably (appropriately) performed, and details thereof will be described later.

[0154] The position detecting apparatus **100** determines whether or not the evaluation result of the evaluation processing indicates "reasonable (OK)" (Step S**11**). When the position detecting apparatus **100** determines that the evaluation result indicates "reasonable" (OK in Step S**11**), the series of calibration processing ends, and the aforementioned operation processing is performed.

[0155] Meanwhile, if the position detecting apparatus **100** determines that the evaluation result of the evaluation processing does not indicate reasonable (OK) (NG in Step S**11**), an output requiring cause analysis is provided (Step S**15**).

[0156] Specifically, the display data generation unit **85** generates data for displaying each sampling position **20** stored in the position storage unit **80** and the target position **21** associated with the sampling position **20** in the same coordinate space in Step S**15** and outputs the generated display data to the display controller **114** (Step S**7**). In this manner, a screen for displaying each sampling position **20** and the target position **21** in an associated manner in the same coordinate space is output to the display unit **132**.

[0157] In addition, the evaluation unit **70** retrieves the cause storage unit **90** and specifies cause data Ri including evaluation content RA corresponding to the evaluation result in Step S**15**. Then, the evaluation unit **70** outputs the specified cause data Ri to the display data generation unit **85**. The display data generation unit **85** generates display data from the cause data Ri and outputs the generated display data to the display controller **114**. In this manner, it is possible to display the cause data Ri (an estimated cause RB or a countermeasure) that is considered to have caused the unreasonable calibration on the display unit **132**.

[0158] The user adjusts the respective parts (Step S**17**). Specifically, it is possible to provide information for supporting adjustment of calibration to the user from the content displayed on the display unit **132**, that is, from a screen (hereinafter, also referred to as a position associating screen) in which each sampling position **20** and the target position **21** are associated in the same coordinate space or the cause data Ri (the estimated cause RB or the countermeasure RC) in Step S**17**. After the user performs the adjustment, the position detecting apparatus **100** can be caused to perform the calibration again.

[0159] (F-2. Operation Processing)

[0160] In the embodiment, actual operations for alignment by the position detecting apparatus **100** are performed after the aforementioned adjustment through the calibration is completed. Specifically, referring to FIG. **13**, the position detecting apparatus **100** specifies a feature image that is a partial image corresponding to the feature portion from image data obtained by imaging the object (workpiece **4**) arranged on the upper surface of the stage **2**, detects the position of the specified feature image (Step T**3**), and outputs a control command for the moving mechanism on the basis of the detected position. In this manner, the stage **2** moves such that the workpiece **4** can be arranged (aligned) at an accurate position.

[0161] In addition, it is possible to perform the calibration using the position detecting apparatus **100** provided in an actual operation environment as illustrated in FIG. **13** according to the embodiment. That is, the position detecting apparatus **100** stores one or a plurality of image data items **10** imaged at each target position **21** in advance in the image storage unit **60** and stores position data **30** based on the detection from each image data item **10** in the position storage unit **80**. During actual operations, the evaluation unit **70** performs evaluation on the calibration (determination of reasonability) by using content in the image storage unit **60** and the position storage unit **80**. In this manner, it is possible to omit the number of processes related to the processing of storing the image data **10** in the image storage unit **60** and the processing of storing the position data **30** in the position storage unit **80**, that is, the processing in Steps S**1**, S**3**, S**13**, and S**14** in FIG. **14** even if the calibration is performed in the actual operations.

G. DISPLAY EXAMPLE OF POSITION ASSOCIATING SCREEN

[0162] FIGS. **15**A-**15**D, **16**, and **17** are diagrams illustrating examples of the position associating screen according to the embodiment. In the associating screen in FIGS. **15**A, **16**, and **17**, each target position **21** and the sampling position **20** associated with the target position **21** in the position storage unit **80** are represented by different icons (icons of plus marks, for example) in the actual coordinate system that is an XY two-dimensional space.

[0163] In addition, in FIG. **15**B, the feature image **22** associated with the target position **21** in the position storage unit **80** is displayed at each target position **21** in the similar actual coordinate system.

[0164] The position associating screen in FIG. **15**C is different from that in FIG. **15**A in that each target position **21** and the sampling position **20** associated with the target position **21** in the position storage unit **80** are represented by different icons (plus icons, for example) in a coordinate system in a monoaxial (an X axis, for example) direction in the actual coordinate system. In addition, on the position associating screen in FIG. **15**D, the minimum difference and the maximum difference from among differences (errors) between the respective target positions **21** in a coordinate system in a monoaxial (an X axis, for example) direction in the actual coordinate system and the plurality of respective sampling positions **20** associated with the target positions **21** in the position storage unit **80** are represented in an associated manner by using a data table.

[0165] In the case of the calibration illustrated in FIGS. **15**A to **17**, the evaluation unit **70** calculates the differences between the plurality of sampling positions **20** and the associated target positions **21** in the position storage unit **80** and evaluates the calculated differences by using reference data **35**, for example, in the evaluation processing. The reference data **35** includes a threshold value of the differences, for example. The evaluation unit **70** outputs “reasonable (OK)” as a result of the evaluation when the evaluation unit **70** determines that a condition (the calculated differences ≤the threshold for the differences) is satisfied for all the target positions **21** while the evaluation unit **70** outputs “not reasonable (OK)” as a result of the evaluation in a case in which the evaluation unit **70** determines that the condition (the calculated differences ≤the threshold for the differences) is not satisfied for all the target positions **21**, for example.

[0166] (G-1. Example of Screen that Displays Precision of Variations in Repeated Samplings)

[0167] FIGS. **18** and **19** are diagrams illustrating an example of the position associating screen that displays variations in the sampling positions according to the embodiment. The user can cause the position associating screen in FIG. **18** that represents results of sampling performed a plurality of times at the respective target positions **21** to be displayed by operating a tab **180** on the screen.

[0168] The position associating screen in FIG. **18** is an example of the screen in a case in which the plurality of sampling positions **20** are detected for the respective target positions **21** by repeating the calibration. The screen in FIG. **18** includes sampling data tables **181** and **182** and a display region **183** of the sampling positions **20**.

[0169] The sampling data tables **181** and **182** include sampling result checking information, sampling result comparison information, and display forms to improve visibility of the information, for example. Specifically, the sampling result checking information includes all data items (positions, difference values, and the like) related to the sampling positions **20** and statistical values (values such as a maximum value, a minimum value, an average value, a standard deviation indicating a degree of variation and the like) of the sampling positions **20**, for example. The measurement result comparison information includes information for comparing the target positions **21** and the sampling positions **20** in the form of a table and information for comparing acquired data including the sampling positions **20** obtained by the calibration performed in the past and acquired data including the sampling positions **20** obtained by the calibration performed this time in the form of a table, for example.

[0170] For the improvement in the visibility of the information, the measurement results (values indicating variations in the sampling positions **20**, the sampling positions **20**, and the like) that are equal to or greater than a specific value are displayed in a form (emphasized display, for example) that is different from that for the other values in the tables, for example, and the statistical values of the sampling positions **20** are displayed in a form (emphasized display, for example) that is different from that for the other values, for example, in the sampling data tables **181** and **182**.

[0171] In addition, the display region **183** of the sampling positions **20** includes information for checking the sampling positions **20** in association with the target positions **21**, comparison information, and display form for improving the visibility. For example, the plurality of associated sampling positions **20** are displayed in the form of scatter plots for each target position **21** in the two-dimensional coordinate space.

[0172] On the basis of such comparison information, marks of the target positions **21** and the sampling positions **20** are presented by being displayed in an overlapping manner or an aligned manner at the target positions **21**. In addition, comparison display between the calibration data obtained in the past and the calibration data obtained this time is presented (displayed in an overlapping manner or in an aligned manner).

[0173] In addition, as the display form to improve the visibility, the sampling positions **20** or the values of the variations thereof that are equal to or greater than a specific value are displayed in a form (emphasized display) that is different from that for the other value, and the statistical values of the sampling positions **20** are displayed in a form (emphasized display) that is different from that for the other values in a manner similar to that in the sampling data tales **181** and **182**. Circular marks around the target positions **21** are displayed in the display region **183**. The diameter of the marks corresponds to the aforementioned specific threshold value. Therefore, sampling positions that have variations with differences of less than the specific threshold value from the target positions **21** are marked inside the circles while the sampling positions **20** that vary with the differences of equal to or greater than the specific threshold value are marked outside the circles. Therefore, it is possible to visually provide the degrees of variations of the sampling positions **20** relative to the respective target positions **21** to the user.

[0174] FIG. **19** illustrates a modification example of the position associating screen in FIG. **18**. The screen in FIG. **19** includes a display region **192** of the feature image **22**, a display region **191** of the sampling results, and an enlarged display region **183**A in which the sampling positions **20** are displayed in an enlarged manner.

[0175] The display region **192** of the image displays the image data **10** or the feature image **22** that is actually imaged, for example. In this manner, the information for checking the sampling results is provided.

[0176] The display region **192** of the image displays information for comparing the sampling results, for example. For example, the display region **192** provides information for comparing a plurality of image data items by displaying, in a comparative manner (displayed in the overlapping manner or in the aligned manner), ideal image data (reference image data), the image data acquired by the calibration performed in the past, and new image data. For example, the detected images (the image data **10** or the feature image **22**) and the ideal image are displayed in the comparative manner (displayed in the overlapping manner or in the aligned manner).

[0177] The display region **192** displays an image (the image data **10** or the feature image **22**) associated with a sampling position **20** with the maximum difference from the target position **21** and an image (the image data **10** or the feature image **22**) associated with a sampling position **20** with the minimum difference in the comparative form (displayed in the overlapping manner or in the aligned manner).

[0178] In addition, the display region **192** displays the feature image **22** in association with the reference image of the target positions **21** in a graphically comparative manner (displays them in the overlapping manner or in the aligned manner). The reference image of the target positions **21** is included in the reference data **35**.

[0179] The enlarged display region **183**A of the sampling positions **20** displays information that is similar to that displayed in the display region **183**A in FIG. **18**.

[0180] The display region **191** displays changes in the sampling positions **20** by a graph in a coordinate space. For example, differences of the respective sampling positions **20** associated with the target positions **21** from the target positions **21** are displayed in a form of a chronological order that follows relative time elapse from the start of the plurality of samplings. For example, the differences from the sampling positions **20** or the target positions **21** or the like are displayed in a chronological order in accordance with the sampling order. Alternatively, the horizontal axis of the coordinates is assigned to a sampling time or a relative time from the first measurement, and a situation (a time required for convergence or the like) in which a difference of a sampling position **20** associated with a certain target position **21** from the target position **21** (see the broken line in the drawing) converges to be less than a specific threshold value (see the solid line in the drawing) indicated by the reference data **35** is visually presented in the display region **191** as illustrated in FIG. **19**.

[0181] (G-2. Example of Screen that Displays Effects of Distortion Correction)

[0182] FIG. **20** is a diagram illustrating an example of the position associating screen that displays effects of the distortion correction according to the embodiment. The user can cause the screen in FIG. **20** to be displayed by operating a tab **200** on the screen.

[0183] The screen in FIG. **20** includes sampling data tables **201**, **202**, and **203**, display regions **204** and **205** of the sampling positions **20**, and a current setting pattern **206** set by a parameter table **121** or the like. In the embodiment, it is possible to set patterns "No. 1" to "No. 4" in the sampling data table **201**, for example, and data of the setting pattern No. 3, for example, among them is displayed in FIG. **20**. Note that the number of setting patterns is not limited to these four patterns. In addition, the setting patterns of the data displayed on the screen in FIG. **20** can be switched.

[0184] The sampling data table **201** includes the maximum value and the minimum value of differences in the X axis direction so as to correspond to the respective setting patterns for correction processing based on the parameter table **121** or the like. The sampling data table **202** includes differences in the X axis direction in association with the respective target positions **21** in calibration in the setting patterns so as to correspond to the respective setting patterns in the sampling data table **202**. The sampling data table **203** includes differences in the Y axis direction in association with the respective target positions **21** in the calibration in the setting patterns so as to correspond to the respective setting patterns of the sampling data table **202**. Note that the sampling data tables **201** to **203** can include all the data items about the sampling positions **20** (for example, the differences from the target positions **21**, the target positions **21**, the sampling positions **20**, and the like) and statistical values of all the data items, for example, in association with the respective setting patterns.

[0185] The sampling data tables **201**. **202**, and **203** can display information related to comparison between setting patterns for correction and data (for example, the target positions **21** and the sampling positions **20**) after the correction processing and comparison between the sampling positions **20** in the past and the latest sampling positions **20**.

Differences that are equal to or greater than a specific value obtained by setting a threshold value or the maximum value of the differences, the minimum value of the differences, and the like are displayed in a form (for example, emphasized display) that is different from that for the other data.

[0186] The display region **204** displays the position associating screen. For example, the display region **204** displays the respective target positions **21** and the sampling positions **20** associated with the target positions **21** in a two-dimensional coordinate space. Further, the display region **204** can display the sampling positions **20** before and after the correction using setting parameters as the sampling positions **20**. In addition, the display region **204** displays auxiliary lines for making it easier to check the respective sampling positions **20**, for example.

[0187] In the embodiment, the auxiliary lines can include line segments **207** and **208** that indicate relative positional relationships between the target positions **21** and the sampling positions **20**, for example. For example, the auxiliary lines can include a line segment **207** connecting the sampling positions **20** associated with the respective target positions **21** in an order of the movement to the respective target positions **21** by the moving mechanism. Alternatively, the auxiliary lines can include a line segment **208** connecting the respective target positions **21** in an order of the movement by the moving mechanism, for example.

[0188] In addition, the sampling positions **20** with differences that are equal to or greater than a specific threshold value can be displayed in a form (emphasized display) that is different from that for the other data in the display region **204**.

[0189] In addition, the display region **204** displays the position associating screen for each setting pattern, for example. Specifically, image processing performed by the image processing unit **50** includes parameters (correction parameters) for a correction function (affine transformation, distortion correction, or the like) for correcting the image data **10** from the amount of movement by the moving mechanism in order to detect the position of the feature portion (mark **14**) from the image data **10** in the embodiment. The image processing unit **50** can detect the respective sampling positions **20** obtained by the image processing before and after the application of the correction function (and/or the correction parameters) as the sampling positions **20** associated with the target positions **21**. In the display region **204**, the sampling positions **20** associated with the target positions **21** can include the respective sampling positions **20** obtained by the image processing before and after the application of the correction function (and/or the correction parameters).

[0190] In addition, the image processing unit **50** can detect the sampling positions **20** by applying setting patterns with different correction parameters in the embodiment. The image processing unit **50** can specify a setting pattern to calculate a sampling position **20** capable of minimizing a difference (or a statistical value) from the target position **21** from among the respective setting patterns and display the position associating screen for the sampling positions **20** and the target positions **21** detected by the specific setting pattern in a display form (for example, emphasized display) that is different from that for the position associating screen based on the other setting patterns.

[0191] The display region **205** displays a pair selected by the user in an enlarged manner from among pairs of the target positions **21** and the sampling positions **20** associated on the position associating screen in the display region **204**. The user can check, in detail, degrees of differences (for example, degrees of differences due to differences in setting patterns) in the detection of the target positions **21** and the sampling positions **20** at the target positions **21** from such enlarged display.

[0192] (G-3. Example of Screen that Displays Precision of Linearity of Sampling)

[0193] FIG. **21** is a diagram illustrating an example of the position associating screen obtained by sampling based on linear movement according to the embodiment. The user can display the screen in FIG. **21** by operating a tab **240** on the screen. The screen in FIG. **21** includes sampling data tables **241** and **242**, a display region **243** of the sampling positions **20**, an image display region **253**, and an enlarged display region **254**.

[0194] The sampling data tables **241** and **242** include all data items (for example, differences in the amounts of movement of the stage **2** (differences from the target positions **21**), the target positions **21**, the sampling positions **20**, target angles, detection angles, and the like) of the sampling positions **20**. The detection angles are inclination angles of the feature image **22** obtained by the image processing unit **50** and indicate inclination angles from a predefined posture of the mark **14** (feature portion).

[0195] In addition, the sampling data tables **241** and **242** can include statistical values and the like of all the data items about the sampling positions **20**.

[0196] The sampling data tables **241** and **242** can include data display in the comparative form of data about the target positions **21** and the sampling positions **20** or data display in the comparative form between all the data items about the sampling positions **20** obtained by the calibration performed in the past and all the data items about the sampling positions **20** obtained by the calibration performed this time, for example.

[0197] In addition, the sampling data tables **241** and **242** display differences that are equal to or greater than a specific threshold value or the sampling positions **20** with the differences in a form (emphasized display) that is different from that for the other data, display the maximum value or the minimum value of the differences in a form (emphasized display) that is different from that for the other data, or display distances between two points, namely the target position **21** and the sampling position **20** with a difference that is equal to or greater than a specific threshold value in a form (emphasized display) that is different from the other data.

[0198] The display region **243** displays a mark **256** at each target position **21** with a predefined posture at each target position **21** in a two-dimensional coordinate space and displays the mark **255** at a sampling position **20** associated with the target position **21** with an inclination angle from the aforementioned predefined posture. The inclination angle corresponds to an inclination angle of the feature image **22** specified from the image data **10** from the predefined posture.

[0199] In addition, the target positions **21** and the sampling positions **20** are displayed by using marks in the overlapping manner or in the aligned manner, for example, in the comparative form in the display region **243**. Also, data of the sampling positions **20** obtained by the calibration performed in the past and data of the sampling positions **20**

obtained by the calibration performed this time are displayed by using marks in the overlapping manner or in the aligned manner, for example, in the comparative form in the display region **243**.

[0200] In addition, the display region **243** displays a mark **14** of a sampling position **20** that has not been sampled at the position, the angle, or the like at the target position **21** in a display form (for example, emphasized display) that is different from that for the other marks. In addition, the distance between two points, namely a target position **21** and a sampling position **20** with a difference that is equal to or greater than a specific threshold value is displayed in a display form (for example, emphasized display) that is different from that for the other distances. In addition, auxiliary lines (for example, the broken lines in the display region **243**) for making it easier to check the respective sampling positions **20** can be displayed in the display region **243**.

[0201] The image display region **253** displays a sampling image (the feature image **22** or the image data **10** that is actually imaged) or a target image (a reference feature image or image data). In this case, the sampling image and the target image can be displayed in the comparative form (displayed in the overlapping manner or in the aligned manner). In addition, the sampling image obtained by the calibration performed in the past and the sampling image obtained by the calibration performed this time can be displayed in the comparative manner (displayed in the overlapping manner or in the aligned manner) in the image display region **253**. In addition, an image and graphics (display and enlarged display of the sampling positions **20**) can be displayed on the comparative form (displayed in the overlapping manner or in the aligned manner).

[0202] The enlarged display region **254** displays the target positions **21** and the sampling positions **20** associated with the target positions **21** as marks in an enlarged manner. In that case, both the marks can be displayed in the comparative manner (displayed in the overlapping manner or in the aligned manner). Targets of the enlarged display can include the sampling positions **20** obtained by the calibration performed in the past and the sampling positions **20** obtained by the calibration performed this time. In addition, marks that have not been sampled at the target positions **21** or at the target angle or the like are displayed in a display form (for example, emphasized display) that is different from that for the other distances in the enlarged display.

[0203] (G-4. Example of Screen that Displays Precision of Sampling During Rotation Movement)

[0204] FIG. **22** is a diagram illustrating an example of the position associating screen obtained by sampling based on rotation movement according to the embodiment. The user can cause the screen in FIG. **22** to be displayed by operating a tab **270** on the screen. The screen in FIG. **22** includes the sampling data tables **181** and **182** that are similar to those in FIG. **18** and a display region **273** of the sampling positions **20**. In the display region **273**, display of the sampling positions **20** (display of the sampling positions **20** associated with the target positions **21**) can be switched to graphic display of rotation sampling in a case in which the moving mechanism is driven to rotate.

[0205] FIG. **23** is a diagram illustrating another example of the position associating screen obtained by sampling based on rotation movement according to the embodiment. The display screen in FIG. **23** is a modification example of the screen in FIG. **22**.

[0206] The screen in FIG. **23** includes the sampling data tables **181** and **182**, the display region **192** of the feature image **22** that is similar to that in FIG. **19**, a sampling result display region **191**, and an enlarged display region **284** of the sampling positions **20**. The enlarged display region **284** displays information that is similar to that in the display region **273** in FIG. **22**.

[0207] (G-5. Example of Screen that Displays Effects of Correction During Rotation Movement)

[0208] FIG. **24** is a diagram illustrating another example of the position associating screen obtained by the sampling based on rotation movement according to the embodiment. The user can cause the screen in FIG. **24** to be displayed by operating a tab **200** on the screen. The screen in FIG. **24** includes the sampling data tables **201**, **202**, and **203** and the current setting pattern **206** set by the parameter table **121** or the like that are similar to those in FIG. **20**. Further, the screen in FIG. **24** includes a display region **294** of the sampling positions **20** and an enlarged display region **304** of the sampling positions **20**. FIG. **24** illustrates a case in which the rotation center C of the stage **2** has not accurately been estimated by the current setting pattern **206**.

[0209] The display region **294** displays the rotation center C estimated from the sampling positions **20** in a case in which the stage **2** rotates and a target rotation center CT set by the parameter table **121** in a distinguishable form (for example, displays them with a changed display color or with a changed line type) and displays a difference therebetween. The display region **294** includes data for displaying the respective target positions **21** on a circumferential line **296** around the target center position (target rotation center CT) or data for displaying the sampling positions **20** associated with the respective target positions **21** on a circumferential line **295** around an estimated center position (that is, the estimated rotation center C). The display region **294** displays the estimated rotation center C and the target rotation center CT in the distinguishable form (for example, with a changed display color or with a changed line type). In addition, the display region **294** displays the circumferential line **295** connecting the sampling positions **20** sampled during the rotation movement around the estimated rotation center C as a center and the circumferential line **296** connecting the target positions **21** around the target rotation center C as a center in the distinguishable form (for example, with a changed display color or with a changed line type).

[0210] In addition, the enlarged display region **304** displays the sampling positions **20** obtained by the rotation movement in the enlarged manner. For example, the marks indicating the target positions **21** and the marks indicating the sampling positions **20** associated with the target positions **21** are displayed in the distinguishable form (for example, displayed with a changed display color or with a changed line type).

[0211] (G-6. Another Example of Screen that Displays Effects of Correction During Rotation Movement)

[0212] FIG. **25** is a diagram illustrating another example of the position associating screen obtained by sampling based on rotation movement according to the embodiment. The user can cause the screen in FIG. **25** to be displayed by operating a tab **320** on the screen. The screen in FIG. **25** includes the sampling data tables **241** and **242** that are similar to those in FIG. **21**, a display region **323** of the sampling positions **20**, an enlarged display region **333** of the sampling positions **20**, and a feature display region **334**. In FIG. **25**, the sampling data tables **241** and **242** can further include all data items (including the sampling positions **20**, the target positions **21**, and the position of the estimated rotation center C, for example) of the sampling positions **20**.

[0213] In FIG. **25**, the sampling data tables **241** and **242** can further include all data about the sampling positions **20** (for example, the sampling positions **20**, the target positions **21**, and the estimated position of the rotation center C).

[0214] The display region **323** displays the positions of the estimated rotation center C and the target center CT with marks, for example, and displays a target sampling circumferential line. Information that is similar to that in the enlarged display region **254** and the image display region **253** in FIG. **21** can be displayed in the enlarged display region **333** and the feature display region **334**, respectively.

[0215] The user can provide support information to determine that only a part of the image data **10** has been able to be calibrated, that the rotation center C of the stage **2** has not appropriately been estimated, that the detected posture (inclination angle) of the feature portion indicated by the results of sampling is not appropriate (the rotation center C of the stage **2** has not appropriately been estimated), that sampling intervals are not equal intervals, and that sampling has not been done at the target positions **21** from the screen in FIG. **23**.

H. EVALUATION OF CALIBRATION

[0216] Evaluation processing performed by the evaluation unit **70** in Step S9 in FIG. **14** will be described. In the embodiment, the evaluation unit **70** evaluates the sampling positions **20** by mainly comparing differences between the target positions **21** and the sampling positions **20** associated with the target positions **21** with the threshold value indicated by the reference data **35** by using predefined evaluation conditions. In addition, the evaluation unit **70** retrieves the cause storage unit **90** on the basis of the evaluation obtained by the evaluation processing and reads the cause data Ri associated with evaluation content RA that represent the evaluation from the cause storage unit **90** through the retrieval.

[0217] FIGS. **26** to **31** are diagrams illustrating examples of the cause data Ri according to the embodiment. The evaluation processing and the cause data Ri will be described with reference to FIGS. **26** to **31**.

[0218] (H-1. Evaluation of Sampling Positions **20** Using Feature Image **22**)

[0219] The evaluation unit **70** calculates differences (also referred to as detection differences) between the respective target positions **21** and the sampling positions **20** associated with the target positions **21** and matches the feature image **22** associated with the sampling positions **20** with a reference image of the mark **14**. Note that the reference data **35** has the reference image of the mark **14**. The evaluation unit **70** evaluates that “there are points at which the target positions and the sampling position **20** do not coincide” when the evaluation unit **70** detects sampling positions **20** that satisfy predefined conditions ((a detection difference a specific threshold value of reference data **35**) and (inconsistent with feature image **22**)) from among the sampling positions **20** associated with the respective target positions **21**. The evaluation unit **70** reads cause data R**1** (FIG. **26**) associated with the aforementioned evaluation (evaluation content RA) from the cause storage unit **90**.

[0220] The user can check that the calibration is “not reasonable” and acquire information about the estimated cause RB (for example, erroneous detection of a background portion other than a target mark at an inconsistent point) and the countermeasure to address the cause (to adjust search setting (a model image, a setting parameter, or the like) by the cause data R**1** being displayed.

[0221] In this case, the screens in FIG. **15**A and FIG. **15**B can also be displayed, for example. The user can check that the sampling has failed at a target position **21** at the upper right end in the field of view of the camera from the position associating screen in FIG. **15**A. In addition, the user can determine that the background image instead of the feature image **22** has been specified by the image processing at the target position **21** from the screen in FIG. **15**B.

[0222] In addition, the position associating screen illustrated in FIG. **18** or **19** may be displayed as the position associating screen.

[0223] (H-2. Evaluation of Trend of Differences in Sampling Positions **20**)

[0224] The evaluation unit **70** calculates the detection differences between the respective target positions **21** and the sampling positions **20** associated with the target positions **21** and evaluates that “the amount of deviation of a sampling position increases by a specific amount in the X direction”, for example, when the evaluation unit **70** detects that a detection difference of the sampling position **20**, which satisfies a predefined condition (detection difference a specific threshold value of reference data **35**), has a trend to appear in the X direction or the Y direction. The evaluation unit **70** reads cause data R**2** (FIG. **26**) associated with the evaluation (evaluation content RA) from the cause storage unit **90**.

[0225] The user can check that the calibration is “not reasonable” and acquire information of the estimated cause RB (for example, a driving condition of the moving mechanism (the amount of movement of the stage is inappropriate, for example)) and the countermeasure RC (to check the control of the stage, for example) to address the cause by the cause data R**2** being displayed.

[0226] In this case, the position associating screen in FIG. **16**, for example, can be displayed. The user can check that there is a trend that differences occur in the X direction from the target positions **21** in the field of view of the camera from the screen in FIG. **16**. In addition, the position associating screen illustrated in FIG. **18** or **19** may be displayed as the position associating screen.

[0227] (H-3. Evaluation of Difference from Target Position **21** at Image End Portion)

[0228] The evaluation unit **70** calculates detection differences between the respective target positions **21** and the sampling positions **20** associated with the target positions **21** and evaluates that “there is a point at which the target position and the sampling position do not coincide at an image end” when the evaluation unit **70** determines that a sampling position **20** that satisfies a predefined condition (the detection difference the specific threshold value of the reference data **35**) is detected at the end portion of the image. The evaluation unit **70** reads cause data R**3** (FIG. **26**) associated with the evaluation (evaluation content RA) from the cause storage unit **90**.

[0229] The user can check that the calibration is "not reasonable" and acquire information of the estimated cause RB (for example, an imaging condition (for example, an influence of camera lens distortion)) and the countermeasure RC (for example, to change the lens to a lens with no strain in the field of view) to address the cause by the cause data R3 being displayed.

[0230] In this case, the screen in FIG. **17**, for example, can also be displayed. The user can check that the sampling has failed at the target position **21** at the end portion of the field of view (image) of the camera from the position associating screen in FIG. **17**. In addition, the position associating screen illustrated in FIG. **29** may be displayed as the position associating screen.

[0231] (H-4. Evaluation of Variations in Differences from Target Positions **21**)

[0232] The evaluation unit **70** calculates the detection differences between the respective target positions **21** and the sampling positions **20** associated with the target positions **21** and evaluates that variations in sampling are large when the evaluation unit **70** determines that a predefined condition (a value of variation in the detection difference a specific threshold value of the reference data **35**) is satisfied. The evaluation unit **70** reads cause data R**4** (FIG. **27**) associated with the evaluation (evaluation content RA) from the cause storage unit **90**. Note that the variation values are values that indicate magnitudes of variations, and the evaluation unit **70** can calculate the variation values from a standard deviation of the detection differences, for example.

[0233] The user can check that the calibration is "not reasonable" and acquire information of the estimated cause RB indicated by the cause data R**4** and the countermeasure RC to address the cause by the cause data R**4** being displayed.

[0234] In this case, the screens in FIGS. **18** and **19**, for example, can also be displayed. The user can check the variation values from the position associating screens in FIGS. **18** and **19**.

[0235] (H-5. Evaluation of Differences from Target Positions **21** Before and after Correction Processing)

[0236] In the embodiment, it is possible to perform calibration while changing the setting pattern of a function parameter for mapping the camera coordinate system to the actual coordinate system. Therefore, the evaluation unit **70** can compare the detection differences between the target positions **21** and the sampling positions **20** in a case in which the calibration is performed after the setting pattern is changed to a new setting pattern and the detection differences of the target positions **21** in a case in which the calibration is performed by the setting pattern before the change.

[0237] Specifically, the evaluation unit **70** evaluates that "the error of the sampling is still large even with the setting for the correction processing" when the evaluation unit **70** determines that a predefined condition (a detection difference after the change of the setting pattern a detection difference before the change) is satisfied. The evaluation unit **70** reads cause data R**5** (FIG. **27**) associated with the evaluation (evaluation content RA) from the cause storage unit **90**.

[0238] The user can check that the calibration is "not reasonable" and acquire information of the estimated cause RB (for example, the setting of the image processing is inappropriate) indicated by the cause data R**5** and the countermeasure RC (setting of the image correction processing is checked and adjusted) to address the cause by the cause data R**5** being displayed.

[0239] In this case, the position associating screen in FIG. **20**, for example, can also be displayed. The user can check a change of differences between the target positions **21** and the sampling positions **20** before and after the change of the setting pattern from the position associating screen in FIG. **20**.

[0240] (H-6. Evaluation of Differences from Target Positions **21** with Angles)

[0241] The evaluation unit **70** detects an inclination of the feature image **22** associated with the sampling positions **20** by matching the feature image **22** with the reference image that the reference data **35** has and evaluates that "the posture (angle) of the sampling is not constant" when the evaluation unit **70** determines that the detected inclination satisfies a predefined condition (the magnitude of the inclination ≥a specific threshold value of the reference data **35**). The evaluation unit **70** reads cause data R**6** (FIG. **28**) associated with the evaluation (evaluation content RA) from the cause storage unit **90**.

[0242] The user can check that the calibration is "not reasonable" and acquire information of the estimated cause RB (for example, parameters for image processing (for example, setting for detecting the rotating object is inappropriate (setting for detecting a rotating object is employed for an object that does not rotate)) indicated by the cause data R**6** and the countermeasure RC (to adjust search setting related to detection of the rotating target) by the cause data R**6** being displayed. In this case, the screen in FIG. **21** can be displayed as the position associating screen. The user can specifically check the degree of the magnitude of the inclination from the position associating screen in FIG. **21**.

[0243] (H-7. Evaluation of Calibration Range from Differences from Target Positions **21**)

[0244] The evaluation unit **70** evaluates whether or not the sampling has been performed at the respective target positions **21** on the basis of whether or not the sampling positions **20** have been stored in association with the respective target positions **21** in the position storage unit **80**. When the evaluation unit **70** determines that the sampling positions **20** have not been stored, the evaluation unit **70** evaluates that "the calibration has been able to be done only for a part of the image". The evaluation unit **70** reads cause data R**7** (FIG. **28**) associated with the evaluation (evaluation content RA) from the cause storage unit **90**.

[0245] The user can check that the calibration is "not reasonable" and acquire information of estimated cause RB (for example, a parameter (for example, setting of a calibration (sampling) range is inappropriate and is excessively narrow) of the image processing) indicated by the cause data R**7** and the countermeasure RC (for example, the setting of the calibration range is reviewed, and the setting is adjusted) to address the cause along with specific information RC**1** about the countermeasure by the cause data R**7** being displayed.

[0246] (H-8. Evaluation of Variations of Differences from Target Positions **21** During Rotation Movement)

[0247] The evaluation unit **70** calculates detection differences between the respective target positions **21** and the sampling positions **20** associated with the target positions **21** during the rotation movement and evaluates that "variations in sampling are large (stopping of the rotation of the stage has not accurately been estimated)" when the evaluation unit **70** determines that a predefined condition (variation values of the detection differences ≥a specific threshold value of the reference data **35**) is satisfied. The evaluation unit **70** reads cause data R**8** (FIG. **29**) associated with the evaluation (evaluation content RA) from the cause storage unit **90**.

[0248] The user can check that the calibration is "not reasonable" and acquire information of the estimated cause RB indicated by the cause data R**8** and the countermeasure RC to address the cause by the cause data R**8** being displayed.

[0249] In this case, the position associating screens in FIGS. **22** and **23**, for example, can also be displayed. The user can check the degrees of variations from the position associating screens in FIGS. **22** and **23**.

[0250] (H-9. Evaluation of Differences from Target Positions **21** Before and after Correction Processing During Rotation Movement)

[0251] The evaluation unit **70** evaluates that "the sampling error is large even with the setting for the correction processing" when the evaluation unit **70** determines that a predefined condition (differences after the change of the setting pattern differences before the change) is satisfied during the rotation movement. The evaluation unit **70** reads cause data R**9** (FIG. **29**) associated with the evaluation (evaluation content RA) from the cause storage unit **90**.

[0252] The user can check that the calibration is "not reasonable" and acquire information of the estimated cause RB (for example, the setting for the image correction processing is inappropriate) indicated by the cause data R**9** and the countermeasure RC (the setting for the image correction processing is checked and adjusted) to address the cause by the cause data R**9** being displayed.

[0253] In this case, the position associating screen in FIG. **24**, for example, can also be displayed. The user can check the changes in the differences between the target positions **21** and the sampling positions **20** before and after the change of the setting pattern from the position associating screen in FIG. **24**.

[0254] (H-10. Evaluation of Calibration Range from Differences from Target Positions **21** During Rotation Movement)

[0255] The evaluation unit **70** evaluates whether or not the sampling has been performed at the respective target positions **21** during the rotation movement on the basis of whether or not the sampling positions **20** have been stored in association with the respective target positions **21** in the position storage unit **80**. When the evaluation unit **70** determines that the sampling positions **20** have not been stored, the evaluation unit **70** evaluates that "the calibration has been able to be performed only on a part of the image (the rotation center of the stage has not accurately been estimated)". The evaluation unit **70** reads cause data R**10** (FIG. **30**) associated with the evaluation (evaluation content RA) from the cause storage unit **90**.

[0256] The user can check that the calibration is "not reasonable" and acquire information of the estimated cause RB (a driving condition of the moving mechanism and parameter setting for the image processing (for example, the setting value of the sampling angle range is inappropriate)) indicated by the cause data R**10** and the countermeasure RC to address the cause (for example, whether or not the setting value of the angle range is reasonable (in particular, whether or not the angle range is too small) is checked, and the setting is adjusted) along with specific information RC**1** of the countermeasure by the cause data R**10** being displayed. In this case, the screen in FIG. **25** can be displayed as the position associating screen.

[0257] (H-11. Evaluation of Differences from Target Positions **21** During Rotation Movement with Angles)

[0258] The evaluation unit **70** detects the inclination of the feature image **22** associated with the sampling positions **20** during the rotation movement by matching the feature image **22** with the reference image that the reference data **35** has and evaluates that "the posture (angle) of the sampling result is not appropriate (the rotation center of the stage has inappropriately been estimated)" when the evaluation unit **70** determines that the detected inclination satisfies a predefined condition (the magnification of the inclination a specific threshold value of the reference data **35**). The evaluation unit **70** reads cause data R**11** (FIG. **30**) associated with the evaluation (evaluation content RA) from the cause storage unit **90**.

[0259] The user can check that the calibration is "not reasonable" and acquire information of the estimated cause RB (for example, the setting for detecting a rotating object is in appropriate) indicated by the cause data R**11** and the countermeasure EC (for example, search setting related to detection of the rotating object is adjusted) along with the specific information RC**1** of the countermeasure by the cause data R**11** being displayed.

[0260] In a case in which the cause data R**10** or R**11** is output, the screen in FIG. **25** can be displayed as the position associating screen. The user can visually check the estimated rotation center of the stage and the error thereof form the position associating screen in FIG. **25**.

[0261] (H-12. Evaluation of Sampling Intervals)

[0262] In the embodiment, it is estimated that the sampling is also performed at equal intervals in a case in which the target positions **21** are set at equal intervals.

[0263] In regard to this point, the evaluation unit **70** calculates intervals between the sampling positions **20** and variations in the intervals and evaluates that "the sampling intervals are not equal intervals (linearity)" when it is determined that a predefined condition (a magnitude of the variations ≥a specific threshold value of the reference data **35**) is satisfied. The evaluation unit **70** reads cause data R**12** (FIG. **31**) associated with the evaluation (evaluation content RA) from the cause storage unit **90**.

[0264] The user can check that the calibration is "not reasonable" and acquire information of the estimated cause RB (for example, an imaging condition (for example, the camera is not installed perpendicularly to the calibration target)) indicated by the cause data R**12** and the countermeasure RC (for example, the installation angle of the camera is checked and adjusted) along with the specific information RC**1** of the countermeasure by the cause data R**12** being displayed. The user can acquire support information for adjusting an attachment posture of the camera **104** from the cause data R**12** displayed.

[0265] In a case in which the cause data R**12** is output, the position associating screen in FIG. **21** can be displayed in a case of linear movement, and the position associating screen in FIG. **25** can be displayed in a case of rotation movement, as the position associating screen. The user can visually check the variations in the intervals between the sampling positions **20** from the position associating screen in FIG. **21** or **25**.

[0266] (H-13. Evaluation of Sampling Positions from Differences from Target Positions **21**)

[0267] The evaluation unit **70** calculates differences between the respective target positions **21** and the associated sampling positions **20** and evaluates that "the measurement has not been able to be performed at ideal sampling positions (linearity) when the evaluation unit **70** determines that the statistical values of the calculated differences satisfy a predefined condition (statistical values ≥a specific threshold value of the reference data **35**). The evaluation unit **70** reads cause data R**13** (FIG. **31**) associated with the evaluation (evaluation content RA) from the cause storage unit **90**.

[0268] The user can check that the calibration is "not reasonable" and acquire information of the estimated cause RB indicated by the cause data R**13** and the countermeasure RC by the cause data R**13** being displayed. The cause data R**13** indicates estimation that the estimated cause RB is in the moving mechanism of the stage, for example, and indicates information that an inspection related to the precision of the stage, for example, is to be performed as the countermeasure RC.

[0269] In a case in which the cause data R**13** is output, the position associating screen in FIG. **21** can be displayed in the case of linear movement, and the position associating screen in FIG. **25** can be displayed in the case of rotation movement, as the position associating screen. The user can visually check the differences of the respective sampling positions **20** from the target positions **21** from the position associating screen in FIG. **21** or **25**.

[0270] <1. Illustration of User Interface (UI) Screen>

[0271] FIGS. **32** to **35** are diagrams of a user interface (UI) screen as illustration to be displayed during the calibration according to the embodiment. First, FIGS. **32** and **33** illustrate screens that represent results of sampling performed a plurality of times at the respective target positions **21**, and the screens in FIGS. **32** and **33** are displayed by clicking a tab **360**.

[0272] In FIG. **32**, information of a target position **21** specified with the position No. 3, for example, is displayed. Specifically, values of a plurality of sampling positions **20** obtained by sampling performed a plurality of times at the target position **21** with the position No. "3" are represented by scatter plots **363**, and an image of the feature image **22** associated with the target position **21** with the position No. "3" is presented. The user can determine degrees of differences between the target position **21** and the sampling positions **20** from the scatter plots **363**. In addition, if the user operates a button **362**, then a window **361** is displayed, and the cause data Ri based on the evaluation performed by the evaluation unit **70** is output. In the window **361**, vibration of the apparatus is estimated as the estimated cause RB since the differences greatly vary in the scatter plots **363**, for example, and information that a duration time before the start of the sampling is to be elongated after completion of the movement of the stage **2** is displayed as the countermeasure RC.

[0273] In FIG. **33**, a chronological graph **371** is displayed instead of the scatter plots **363** in FIG. **32**. The chronological graph **371** displays differences of the respective sampling positions **20** associated with the target position **21** from the target position **21** in a form of a chronological order that follows relative time elapse from the start of the detection of the plurality of sampling positions **20**. According to the chronological graph **371**, a change in values of the plurality of sampling positions **20** associated with the target position **21** designated by the position No. "3", for example, with elapse of time. The chronological graph **371** in FIG. **33** illustrates that the sampling positions **20** (broken line) at the target position **21** with the position No. "3" converges to a reasonable value at a relatively early timing from the start of the calibration (the start of the detection of the plurality of sampling positions **20**) with reference to a specific threshold value (solid value) of the differences indicated by the reference data **35**, for example. In this manner, the user can check that the vibrations of the apparatus do not affect the sampling.

[0274] Next, FIGS. **34** and **35** illustrate UI screens for checking that the camera **104** has been installed under appropriate imaging conditions or that the driving conditions of the moving mechanism are appropriate.

[0275] Referring to FIG. **34**, the variations in the sampling positions **20** associated with the target positions **21** are represented by the scatter plots **391** in association with the respective target positions **21**. In addition, FIG. **35** illustrates a measurement value graph **411**. The measurement value graph **411** represents changes of the differences between the respective target positions **21** and the associated sampling positions **20** due to relative time elapse from the start of the detection of the plurality of sampling positions **20**. The user can check degrees of the differences between the target positions **21** and the sampling positions **20** at the respective target positions **21** or chronological changes in the difference from the scatter plots **391** or the measurement value graph **411**. In this manner, it is possible to determine whether or not the imaging conditions or the motions of the moving mechanism are appropriate.

K. MODIFICATION EXAMPLE

[0276] The aforementioned embodiment can be modified as follows, for example. For example, it is possible to output, as files, data collected by the calibration (for example, the image data **10**, the position data **30**, various kinds of statistical information and display data obtained by the evaluation unit **70**, and the like) to an external device in relation to a file output function.

[0277] In addition, it is possible to reproduce data display on an external controller by reading the aforementioned output files by the controller, in relation to a file reading function.

[0278] In addition, it is possible to activate a setting screen for a unit that has generated data from a data display screen (for example, a search unit that executes the sampling or image master calibration that has generated calibration data) and change the setting pattern from the activated screen. In addition, it is possible to perform the calibration in the changed setting pattern and to check new results. In addition, it is possible to update calibration parameters other than the aforementioned setting pattern from the activated screen. In a case in which the results of the calibration using the new setting pattern or calibration parameters do not show ideal data, it is also possible to return the data to previous data.

[0279] In addition, it is possible to perform calibration equivalent to that described above even in a case in which the image data **10** indicates three-dimensional image data in the embodiment. In addition, any of image data imaged by a single camera (a three-dimensional (3D) camera, for example) or synthesized image data from image data captured by a plurality of cameras can be applied as the three-dimensional image data.

[0280] In addition, the calibration results (for example, the position associating screen, results of the evaluation performed by the evaluation unit **70**, or the like) may be collected and displayed on the display unit **132** while the position detecting apparatus **100** is caused to run, or alternatively, the calibration results may be displayed without causing the position detecting apparatus **100** to run, for the calibration performed by the position detecting apparatus **100**. For example, the image data **10** imaged during movement to the respective target positions **21** may be accumulated in the image storage unit **60**, and thereafter, image processing of detecting the sampling positions **20**, evaluation processing, and an output using display data may be performed for the image data **10** associated with the respective target positions **21** in the image storage unit **60**.

L. NOTES

[0281] The aforementioned embodiment includes the following technical ideas:

[Configuration 1]

[0282] A position detecting apparatus including: an image storage unit (**60**) that stores image data (**10**) obtained by imaging an object when a feature portion is positioned at a plurality of respective target positions (**21**) by a moving mechanism (**300**) configured to change the position of the object (**4**) in which the feature portion (**14**) for positioning is provided; an image processing unit (**50**) that detects positions of the feature portions included in the image data from the image data through image processing; a position storage unit (**80**) that stores the detected positions detected by the image processing portion in association with the target positions from the image data of the object positioned at the respective target positions; and a display data generation unit (**85**) that generates data for displaying information related to the detected positions on a display unit (**132**), in which the display data generation unit generates data for displaying the respective target positions and the respective detected positions, which are stored in association with the target positions, in a same coordinate space (FIGS. **15**A-**15**D, **16**, and **17**).

[Configuration 2]

[0283] The position detecting apparatus according to Configuration 1, in which the object is moved to the respective target positions a plurality of times by the moving mechanism, and the detected positions stored in association with the respective target positions in the position storage unit include a plurality of detected positions detected from the image data imaged and acquired by being moved to the target positions a plurality of times.

[Configuration 3]

[0284] The position detecting apparatus according to Configuration 2, in which the coordinate space has multidimensional coordinate axes, and the display data generation unit generates data for displaying the target positions and the detected positions associated with the target positions on at least one coordinate axis from among the multidimensional coordinate axes.

[Configuration 4]

[0285] The position detecting apparatus according to Configuration 2 or 3, in which the data for displaying the respective detected positions includes data for displaying the plurality of associated detected positions in a form of scatter plots (**183**) in the coordinate space for each of the target positions.

[Configuration 5]

[0286] The position detecting apparatus according to Configuration 3 or 4, in which the data for displaying the respective detected positions includes data (**191**) for displaying the plurality of associated detected positions in a form of a chronological order that follows relative time elapse from a start of the detection of the plurality of detected positions for each of the target positions.

[Configuration 6]

[0287] The position detecting apparatus according to any one of Configurations 1 to 5, in which the data for displaying the respective detected positions includes data for displaying line segments (**207**; **208**) that indicate relative positional relationships between the respective target positions and the detected positions associated with the target positions.

[Configuration 7]

[0288] The position detecting apparatus according to any one of claims **1** to **6**, wherein the line segments that indicate the relative positional relationships include data for displaying a line segment (**207**) connecting the detected positions associated with the respective target positions in an order of the moving to the target positions by the moving mechanism or data for displaying a line segment (**208**) connecting the respective target positions in the order of the moving by the moving mechanism.

[Configuration 8]

[0289] The position detecting apparatus according to any one of Configurations 1 to 7, in which the moving includes rotational movement of rotating about a predefined target center position (cT) at a center, the target positions include the target center position, and the detected positions include an estimated center position (c) of the rotation, which is estimated from the respective detected positions associated with the respective target positions.

[Configuration 9]

[0290] The position detecting apparatus according to Configuration 8, in which the data for displaying the respective detected positions further includes data for displaying the respective target positions on a circumferential line (**296**) around the target center position at the center or data for displaying the detected positions associated with the respective target positions on a circumferential line (**295**) around the estimated center position at the center.

[Configuration 10]

[0291] The position detecting apparatus according to any one of Configurations 1 to 9, in which the data for displaying the respective detected positions includes data for displaying the detected positions with differences from the associated target positions exceeding a threshold value in a predefined

[Configuration 11]

[0292] The position detecting apparatus according to any one of Configurations 1 to 9, in which the image processing unit detects an inclination angle from a predefined posture of the feature portion from the image of the feature portion, and the data for displaying the respective detected positions includes data for displaying the detected positions associated with the target positions as a mark (**255**) that indicates the inclination angle.

[Configuration 12]

[0293] The position detecting apparatus according to any one of Configuration 1 to 11, in which the object is moved to the respective target positions a plurality of times by the moving mechanism, the detected positions stored in association with the respective target positions in the position storage unit include a plurality of detected positions detected from the image data imaged and acquired by being moved to the target positions a plurality of times, and the display data generation unit further generates data for displaying statistical values of the plurality of detected positions at the target positions in association with the respective target positions.

[Configuration 13]

[0294] The position detecting apparatus according to Configuration 12, in which the statistical values include at least one of a maximum value, a minimum value, and an average value of differences between the plurality of detected positions and the associated target positions.

[Configuration 14]

[0295] The position detecting apparatus according to Configuration 12 or 13, in which the display data generation unit further generates data (**191**) for displaying differences of the plurality of respective detected positions associated with the target positions from the target positions in a form of a chronological order that follows relative time elapse from a start of the detection of the plurality of detected position.

[Configuration 15]

[0296] The position detecting apparatus according to any one of Configurations 12 to 14, in which the display data generation unit associates differences of the plurality of detected positions associated with the target positions from the target positions with predefined threshold values of the differences and generates data (**191**) for displaying the respective detected positions in the form of the chronological order that follows the relative time elapse from the start of the detection of the plurality of detected positions.

[Configuration 16]

[0297] The position detecting apparatus according to any one of Configurations 1 to 15, in which the display data generation unit further includes a portion that generates data (**192**) for displaying the image data of the feature portion at which the detected positions are detected.

[Configuration 17]

[0298] The position detecting apparatus according to any one of Configurations 1 to 16, in which the display data generation unit further includes a portion (**205**) that displays the target positions and the detected positions associated with the target positions in an enlarged manner.

[Configuration 18]

[0299] The position detecting apparatus according to any one of Configurations 1 to 17, in which the image processing includes correction parameters for correcting the image data from an amount of movement of the moving mechanism in order to detect a position of the feature portion from the image data, and the detected positions associated with the target positions include respective detected positions obtained in image processing before and after application of the correction parameters.

[Configuration 19]

[0300] A position detecting apparatus including: an image storage portion (**60**) that stores image data (**10**) obtained by imaging an object when a feature portion (**14**) is positioned at a plurality of target positions by a moving mechanism (**300**) configured to change a position of the object (**4**) in which the feature portion for positioning are provided; an image processing portion (**50**) that detects positions of the feature portion that is included in the image data from the image data through image processing; a position storage portion (**80**) that stores the detected positions detected by the image processing portion in association with the target positions from the image data of the object positioned at the respective target positions; a cause storage portion (**90**) that stores a plurality of predefined cause data items (Ri) that have evaluation content (RA) that represents evaluation of positional differences from the target positions in a coordinate system and an estimated cause (RB) estimated for the positional differences in linkage with the evaluation content; an evaluation portion (**70**) that evaluates detection differences that are differences between the target positions and the associated detected positions in the coordinate system in the position storage portion on a basis of a predefined reference (**35**); and a display data generation portion (**85**) that generates data for displaying information related to the evaluation on a display unit, in which the display data generation portion generates data for displaying the estimated cause in the cause storage portion, which correspond to the evaluation content that represents evaluation by the evaluation portion.

[Configuration 20]

[0301] The position detecting apparatus according to Configuration 19, in which the cause storage portion stores a countermeasure (RC) for addressing the estimated cause in linkage with the estimated cause, and the display data generation portion further generates data for displaying the countermeasure that corresponds to the estimated cause.

[Configuration 21]

[0302] The position detecting apparatus according to Configuration 19, in which the object is moved to the respective target positions a plurality of times by the moving mechanism, and the detected positions stored in association with the respective target positions in the position storage portion include a plurality of detected positions detected from the image data imaged and acquired by being moved to the target positions a plurality of times.

[Configuration 22]

[0303] The position detecting apparatus according to Configuration 21, in which the detection differences include statistical values of the differences between the target positions and the plurality of associated detected positions in the position storage portion.

[Configuration 23]

[0304] The position detecting apparatus according to Configuration 22, in which the statistical values include at least one of values that indicate an average value, a maximum value, a minimum value, and a variation in the differences from the plurality of detected positions.

[Configuration 24]

[0305] The position detecting apparatus according to any one of Configurations 19 to 23, in which the estimated cause includes at least one of a condition for driving the moving mechanism, a parameter for the image processing, and a condition for imaging.

[Configuration 25]

[0306] The position detecting apparatus according to any one of Configurations 19 to 24, wherein the display data generation portion generates data for displaying the respective target positions and the respective detected positions stored in association with the target positions in the same coordinate space (FIGS. **15**A-**15**D, **16**, and **17**).

[Configuration 26]

[0307] A program for causing a computer (**110**) to execute a position detecting method, the position detecting method including the steps of: detecting (S**3**) a position of a feature portion that is included in image data from image data (**10**) acquired by imaging an object through image processing when the feature portion is positioned at a plurality of respective target positions (**21**) by a moving mechanism (**300**) configured to change a position of the object (**4**) in which the feature portion (**14**) for positioning is provided; associating and storing the detected positions (**20**) detected through the image processing with the target positions from the image data of the object positioned at the respective target positions; and generating (S**15**) data for displaying information related to the detected positions on a display unit (**132**), in which in the generating of the data for displaying the information, data (FIGS. **15**A-**15**D, **16**, and **17**) for displaying the respective target positions and the respective detected positioned stored in association with the target positions in a same coordinate space is generated.

[Configuration 27]

[0308] A program for causing a computer (**110**) to execute a position detecting method, the computer including a cause storage unit (**90**) that stores a plurality of predefined cause data items (Ri) that have evaluation content (RA) that represents evaluation of positional differences from the target positions in a coordinate system and an estimated cause (RB) estimated for the positional differences in linkage with the evaluation content, the position detecting method including the steps of: detecting (S**3**) a position of a feature portion that is included in image data from image data (**10**) acquired by imaging an object through image processing when the feature portion is positioned at a plurality of respective target positions by a moving mechanism (**300**) configured to change a position of the object in which the feature portion for positioning is provided; associating and storing the detected positions (**20**) detected through the image processing with the target positions from the image data of the object positioned at the respective target positions; evaluating (S**9**) detection differences that are differences in the coordinate system between the stored target positions and the associated detected positions on a basis of predefined reference; and generating (S**15**) data for displaying information related to the evaluation on a display unit (**132**), in which in the generating of the data to be displayed, data for displaying the estimated cause, which corresponds to the evaluation content that represents the evaluation in the evaluating, in the cause storage unit, in the cause storage unit is generated.

[0309] In the related art, knowhow of a person skilled in positioning is needed, and it takes a time for the user to seek out a cause when the precision required for positioning is not satisfied during running or activation of a positioning device.

[0310] Meanwhile, since the sampling position **20** detected from the image data **10** obtained by imaging the workpiece **4** or the like that has moved to each target position **21** is stored in association with the target position **21**, and the data for displaying each stored sampling position **20** and the target position **21** associated with the sampling position **20** in the same coordinate space is generated in the calibration, such display information can be support information for specifying the aforementioned cause in the embodiment. In this manner, the time taken to seek out the aforementioned cause can be shortened.

[0311] In addition, the evaluation unit **70** evaluates a difference between the sampling position **20** and the target position **21** stored in association in the position storage unit **80** in association with the predefined reference data **35**, a cause that may cause the difference is estimated by the evaluation, and the display data for the estimated cause is generated. In this manner, it is possible to present the estimated cause as support information when the aforementioned cause is sought out and to easily specify a final cause.

[0312] It will be apparent to those skilled in the art that various modifications and variations can be made to the disclosed embodiments without departing from the scope or spirit of the disclosure. In view of the foregoing, it is intended that the disclosure covers modifications and variations provided that they fall within the scope of the following claims and their equivalents. ting apparatus

What is claimed is:

1. A position detecting apparatus comprising:

an image storage portion that stores image data obtained by imaging an object when a feature portion is positioned at a plurality of respective target positions by a moving mechanism configured to change the position of the object in which the feature portion for positioning is provided;

an image processing portion that detects positions of the feature portions included in the image data from the image data through image processing;

a position storage portion that stores the detected positions detected by the image processing portion in association with the target positions from the image data of the object positioned at the respective target positions; and

a display data generation portion that generates data for displaying information related to the detected positions on a display unit,

wherein the display data generation portion generates data for displaying the respective target positions and the respective detected positions, which are stored in association with the target positions, in the same coordinate space.

2. The position detecting apparatus according to claim **1**,

wherein the object is moved to the respective target positions a plurality of times by the moving mechanism, and

the detected positions stored in association with the respective target positions in the position storage portion include a plurality of detected positions detected from the image data imaged and acquired by being moved to the target positions a plurality of times.

3. The position detecting apparatus according to claim **2**,

wherein the coordinate space has multidimensional coordinate axes, and

the display data generation portion generates data for displaying the target positions and the detected positions associated with the target positions on at least one coordinate axis from among the multidimensional coordinate axes.

4. The position detecting apparatus according to claim **2**, wherein the data for displaying the respective detected positions includes data for displaying the plurality of associated detected positions in a form of scatter plots in the coordinate space for each of the target positions.

5. The position detecting apparatus according to claim **3**, wherein the data for displaying the respective detected positions includes data for displaying the plurality of associated detected positions in a form of a chronological order that follows relative time elapse from a start of the detection of the plurality of detected positions for each of the target positions.

6. The position detecting apparatus according to claim **1**, wherein the data for displaying the respective detected positions includes data for displaying line segments that indicate relative positional relationships between the respective target positions and the detected positions associated with the target positions.

7. The position detecting apparatus according to claim **1**, wherein the line segments that indicate the relative positional relationships include data for displaying a line segment connecting the detected positions associated with the respective target positions in an order of the moving to the target positions by the moving mechanism or data for displaying a line segment connecting the respective target positions in the order of the moving by the moving mechanism.

8. The position detecting apparatus according to claim **1**,

wherein the moving includes rotational movement of rotating about a predefined target center position at a center,

the target positions include the target center position, and

the detected positions include an estimated center position of the rotation, which is estimated from the respective detected positions associated with the respective target positions.

9. The position detecting apparatus according to claim **8**, wherein the data for displaying the respective detected positions further includes data for displaying the respective target positions on a circumferential line around the target center position at the center or data for displaying the detected positions associated with the respective target positions on a circumferential line around the estimated center position at the center.

10. The position detecting apparatus according to claim **1**, wherein the data for displaying the respective detected positions includes data for displaying the detected positions with differences from the associated target positions exceeding a threshold value in a predefined form.

11. The position detecting apparatus according to claim **1**,

wherein the image processing portion detects an inclination angle from a predefined posture of the feature portion from the image of the feature portion, and

the data for displaying the respective detected positions includes data for displaying the detected positions associated with the target positions as a mark that indicates the inclination angle.

12. The position detecting apparatus according to claim **1**,

wherein the object is moved to the respective target positions a plurality of times by the moving mechanism,

the detected positions stored in association with the respective target positions in the position storage portion include a plurality of detected positions detected from the image data imaged and acquired by being moved to the target positions a plurality of times, and

the display data generation portion further generates data for displaying statistical values of the plurality of detected positions at the target positions in association with the respective target positions.

13. The position detecting apparatus according to claim **12**, wherein the statistical values include at least one of a maximum value, a minimum value, and an average value of differences between the plurality of detected positions and the associated target positions.

14. The position detecting apparatus according to claim **12**, wherein the display data generation portion further generates data for displaying differences of the plurality of detected positions associated with the target positions from the target positions in a form of a chronological order that follows relative time elapse from a start of the detection of the plurality of detected position.

15. The position detecting apparatus according to claim **12**, wherein the display data generation portion associates differences of the plurality of detected positions associated with the target positions from the target positions with predefined threshold values of the differences and generates data for displaying the respective detected positions in the form of the chronological order that follows the relative time elapse from the start of the detection of the plurality of detected positions.

16. The position detecting apparatus according to claim **1**, wherein the display data generation portion further includes a portion that generates data for displaying the image data of the feature portion at which the detected positions are detected.

17. The position detecting apparatus according to claim **1**, wherein the display data generation portion further includes a portion that displays the target positions and the detected positions associated with the target positions in an enlarged manner.

18. The position detecting apparatus according to claim **1**,

wherein the image processing includes correction parameters for correcting the image data from an amount of movement of the moving mechanism in order to detect a position of the feature portion from the image data, and

the detected positions associated with the target positions include respective detected positions obtained in image processing before and after application of the correction parameters.

19. A position detecting apparatus comprising:

an image storage portion that stores image data obtained by imaging an object when a feature portion is positioned at a plurality of respective target positions by a moving mechanism configured to change a position of the object in which the feature portion for positioning is provided;

an image processing portion that detects positions of the feature portion that is included in the image data from the image data through image processing;

a position storage portion that stores the detected positions detected by the image processing portion in association with the target positions from the image data of the object positioned at the respective target positions;

a cause storage portion that stores a plurality of predefined cause data items that have evaluation content that represents evaluation of positional differences from the target positions in a coordinate system and an estimated cause estimated for the positional differences in linkage with the evaluation content;

an evaluation portion that evaluates detection differences that are differences between the target positions and the associated detected positions in the coordinate system in the position storage portion on the basis of a predefined reference; and

a display data generation portion that generates data for displaying information related to the evaluation on a display unit,

wherein the display data generation portion generates data for displaying the estimated cause in the cause storage portion, which corresponds to the evaluation content that represents evaluation by the evaluation portion.

20. The position detecting apparatus according to claim **19**,

wherein the cause storage portion stores a countermeasure for addressing the estimated cause in linkage with the estimated cause, and

the display data generation portion further generates data for displaying the countermeasure that corresponds to the estimated cause.

21. The position detecting apparatus according to claim **19**,

wherein the object is moved to the respective target positions a plurality of times by the moving mechanism, and

the detected positions stored in association with the respective target positions in the position storage portion include a plurality of detected positions detected from the image data imaged and acquired by being moved to the target positions a plurality of times.

22. The position detecting apparatus according to claim **21**, wherein the detection differences include statistical values of the differences between the target positions and the plurality of associated detected positions in the position storage portion.

23. The position detecting apparatus according to claim **22**, wherein the statistical values include at least one of values that indicate an average value, a maximum value, a minimum value, and a variation in the differences from the plurality of detected positions.

24. The position detecting apparatus according to claim **19**, wherein the estimated cause includes at least one of a condition for driving the moving mechanism, a parameter for the image processing, and a condition for imaging.

25. The position detecting apparatus according to claim **19**, wherein the display data generation portion generates data for displaying the respective target positions and the respective detected positions stored in association with the target positions in the same coordinate space.

26. A non-transitory computer-readable recording medium comprising a program for causing a computer to execute a position detecting method, the position detecting method comprising the steps of:

detecting a position of a feature portion that is included in image data from the image data acquired by imaging an object through image processing when the feature portion is positioned at a plurality of respective target positions by a moving mechanism configured to change a position of the object in which the feature portion for positioning is provided;

storing the detected positions detected through the image processing in association with the target positions from the image data of the object positioned at the respective target positions; and

generating data for displaying information related to the detected positions on a display unit,

wherein the generating of the data for displaying the information includes generating data for displaying the respective target positions and the respective detected positions stored in association with the target positions in the same coordinate space.

27. A non-transitory computer-readable recording medium comprising program for causing a computer to execute a position detecting method, the computer including a cause storage unit that stores a plurality of predefined cause data items that have evaluation content that represents evaluation of positional differences from the target positions in a coordinate system and an estimated cause estimated for the positional differences in linkage with the evaluation content,

the position detecting method comprising the steps of:

detecting a position of a feature portion that is included in image data from the image data acquired by imaging an object through image processing when the feature portion is positioned at a plurality of respective target positions by a moving mechanism configured to change a position of the object in which the feature portion for positioning is provided;

storing the detected positions detected through the image processing in association with the target positions from the image data of the object positioned at the respective target positions;

evaluating detection differences that are differences in the coordinate system between the stored target positions and the associated detected positions on a basis of a predefined reference; and

generating data for displaying information related to the evaluation on a display unit,

wherein, in the generating of the data to be displayed, data for displaying the estimated cause, which corresponds to the evaluation content that represents the evaluation in the evaluating, in the cause storage unit is generated.

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