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(54) **IMAGE INSPECTION DEVICE**

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(73) Assignee: **Keyence Corporation**, Osaka (JP)

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G06T 7/194 (2017.01)
G06V 30/18 (2022.01)

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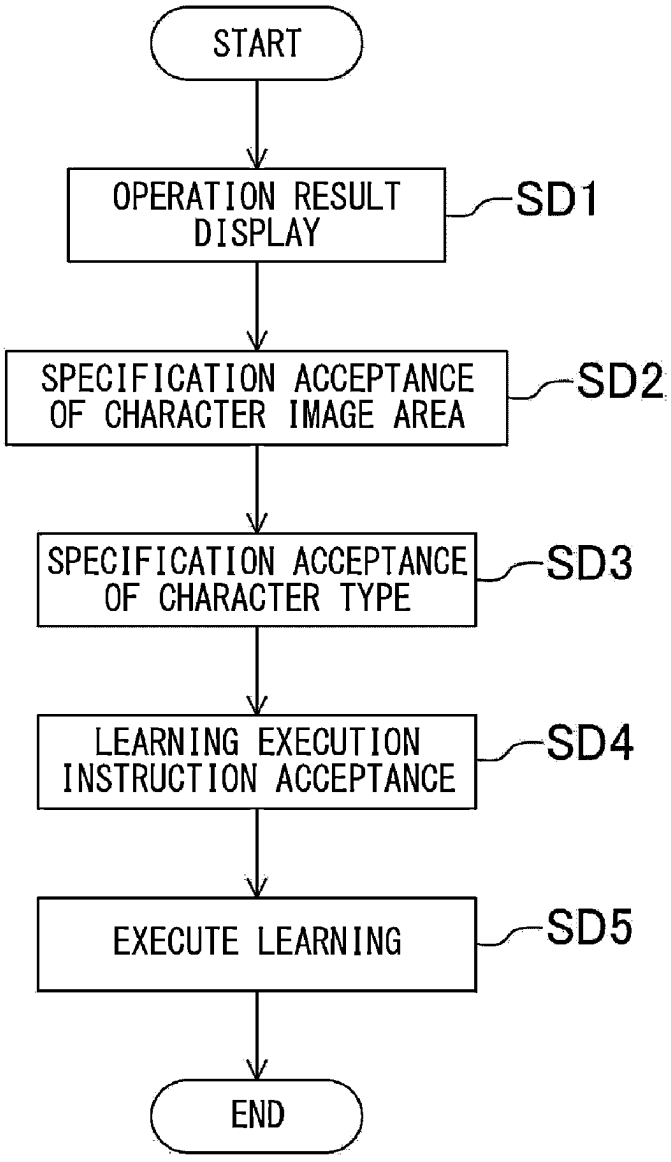
CPC ***G06V 30/19173*** (2022.01); ***G06T 7/194*** (2017.01); ***G06V 30/18057*** (2022.01)

(57) **ABSTRACT**

An image inspection device includes a control unit configured to execute a pre-trained character recognition model and functions as a learning execution unit and a learning data generation unit. The learning data generation unit generates learning data that includes character type information, and size information. The learning execution unit updates the pre-trained character recognition model so as to classify an image area into added character type classes corresponding to the combination of the character type and the size.



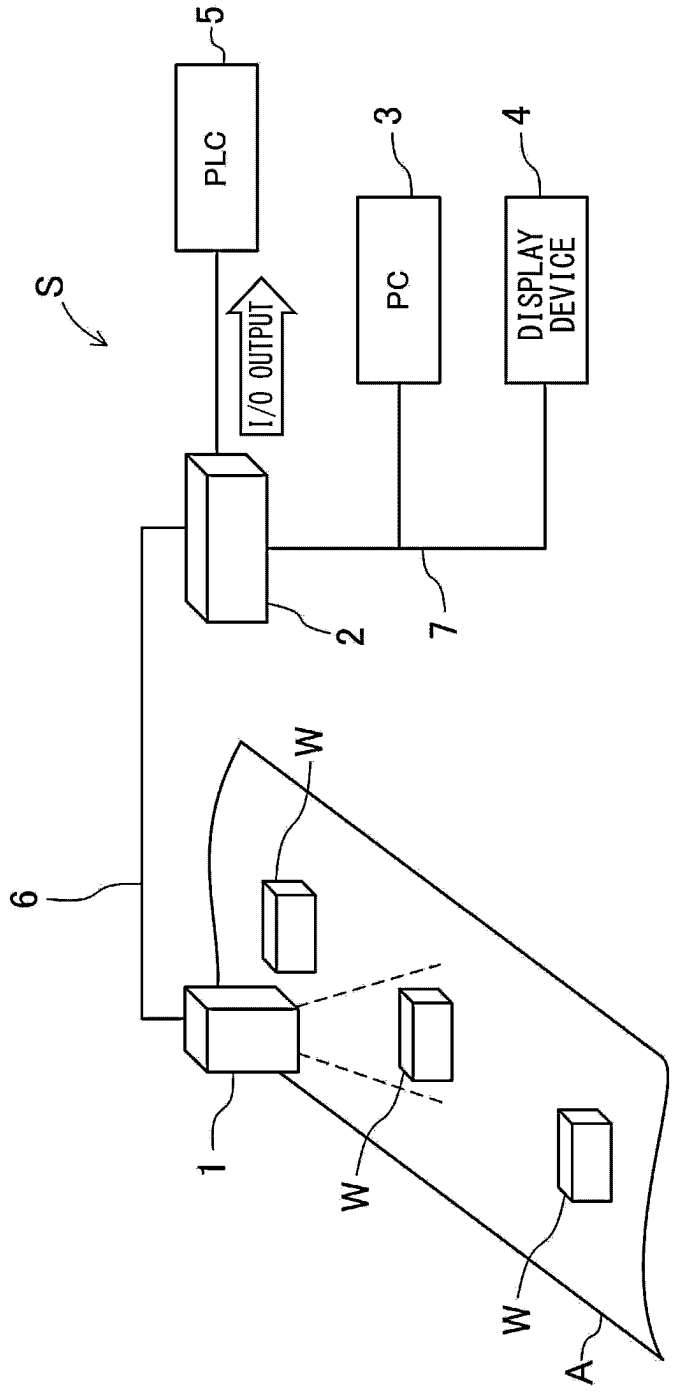


FIG. 1

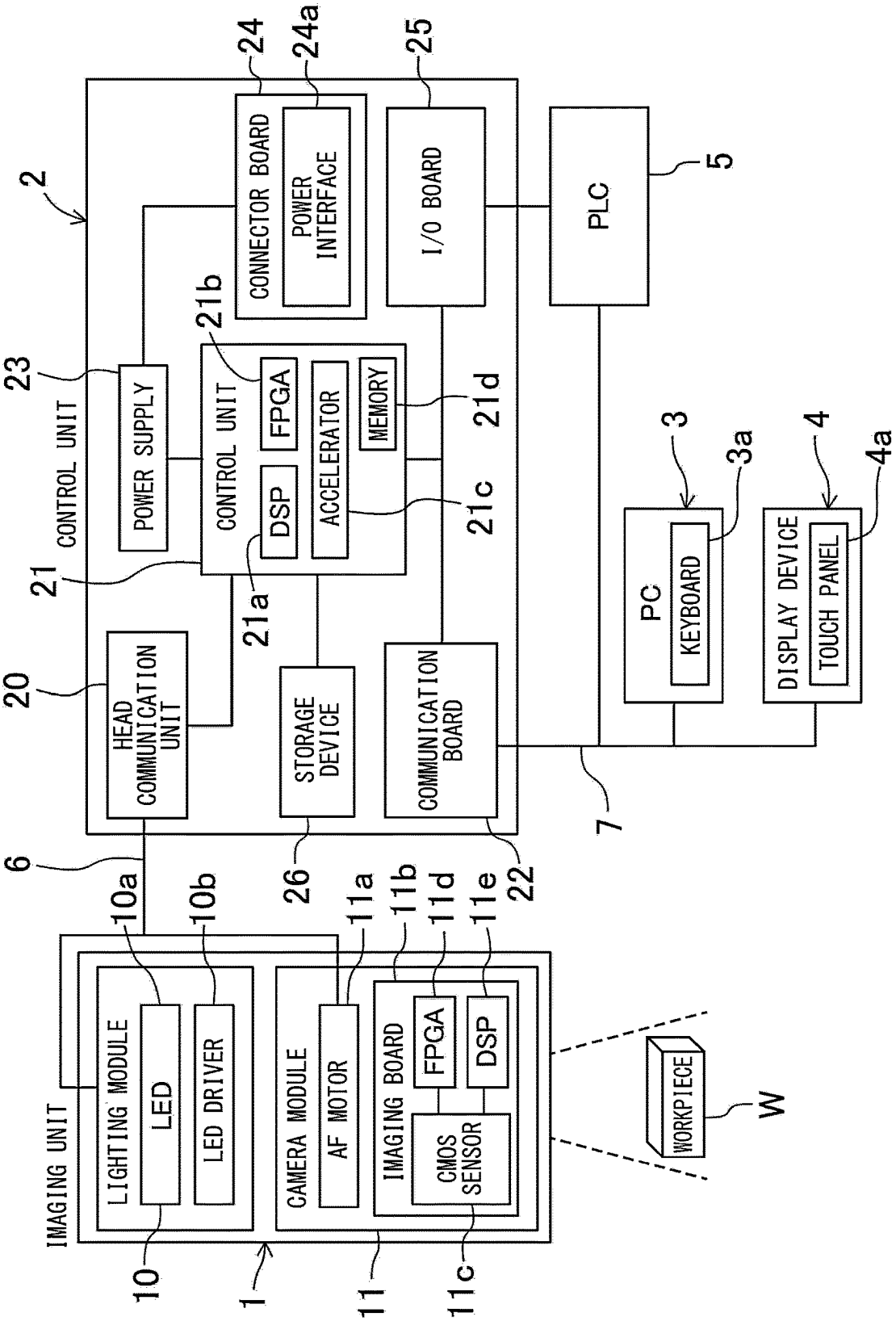

IMAGING UNIT
LIGHTING MODULE
LED
LED DRIVER
CAMERA MODULE
AF MOTOR
IMAGING BOARD
FPGA
DSP
CMOS SENSOR
WORKPIECE
W
10
1
11
11c
6
10a
10b
11a
11b
11d
11e
26
22
2
CONTROL UNIT
POWER SUPPLY
CONTROL UNIT
FPGA
DSP
ACCELERATOR
MEMORY
21
21a
21b
21c
21d
23
CONNECTOR BOARD
POWER INTERFACE
24
24a
I/O BOARD
25
PLC
5
HEAD COMMUNICATION UNIT
20
STORAGE DEVICE
COMMUNICATION BOARD
7
PC
KEYBOARD
3
3a
DISPLAY DEVICE
TOUCH PANEL
4
4a

FIG. 2

FIG. 3

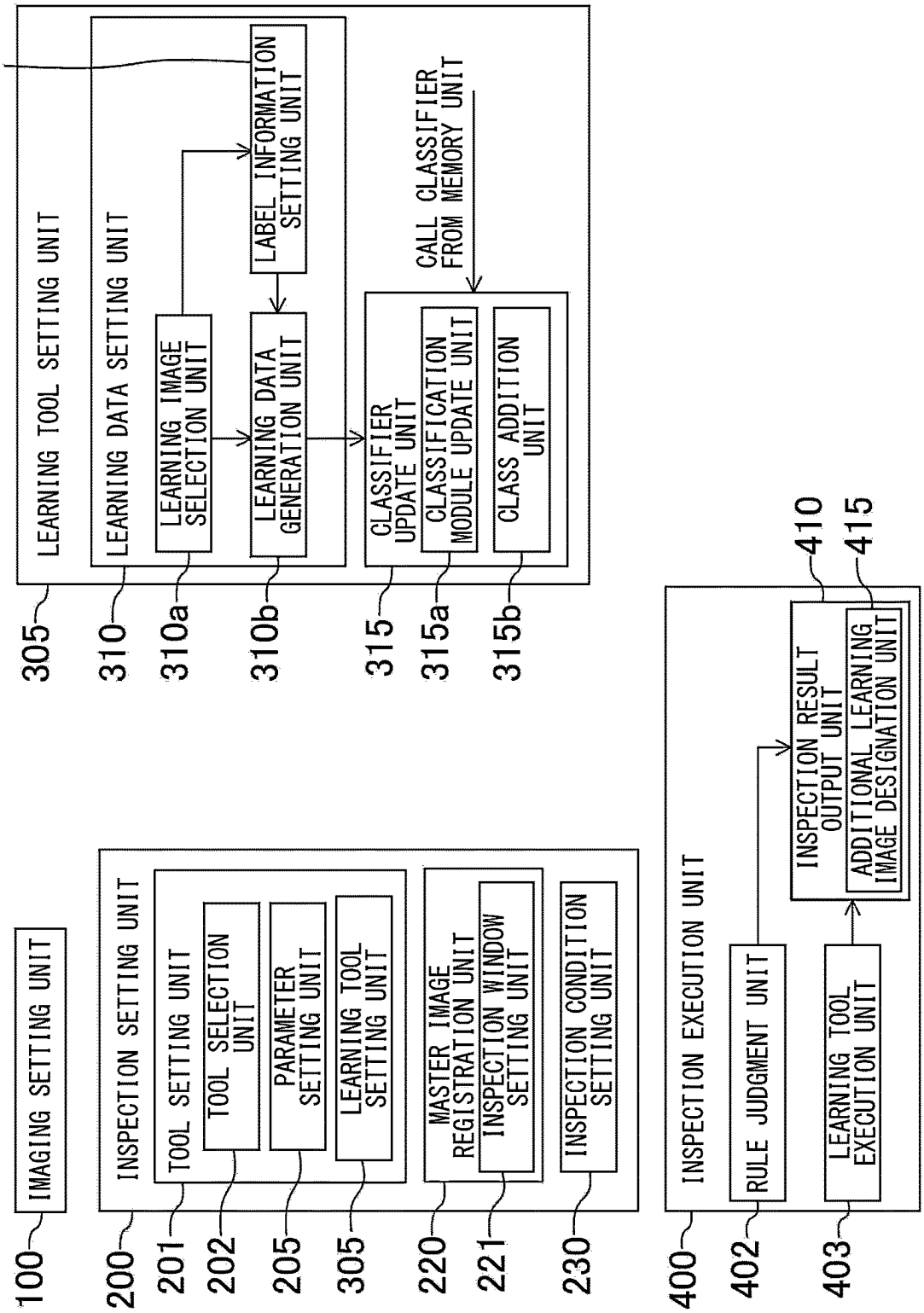

100
IMAGING SETTING UNIT
200
INSPECTION SETTING UNIT
201
TOOL SETTING UNIT
202
TOOL SELECTION UNIT
205
PARAMETER SETTING UNIT
305
LEARNING TOOL SETTING UNIT
220
MASTER IMAGE REGISTRATION UNIT
221
INSPECTION WINDOW SETTING UNIT
230
INSPECTION CONDITION SETTING UNIT
400
INSPECTION EXECUTION UNIT
402
RULE JUDGMENT UNIT
403
LEARNING TOOL EXECUTION UNIT
410
INSPECTION RESULT OUTPUT UNIT
415
ADDITIONAL LEARNING IMAGE DESIGNATION UNIT
305
LEARNING TOOL SETTING UNIT
310
LEARNING DATA SETTING UNIT
310a
LEARNING IMAGE SELECTION UNIT
310b
LEARNING DATA GENERATION UNIT
310c
LABEL INFORMATION SETTING UNIT
315
CLASSIFIER UPDATE UNIT
315a
CLASSIFICATION MODULE UPDATE UNIT
315b
CLASS ADDITION UNIT
CALL CLASSIFIER FROM MEMORY UNIT

FIG. 4

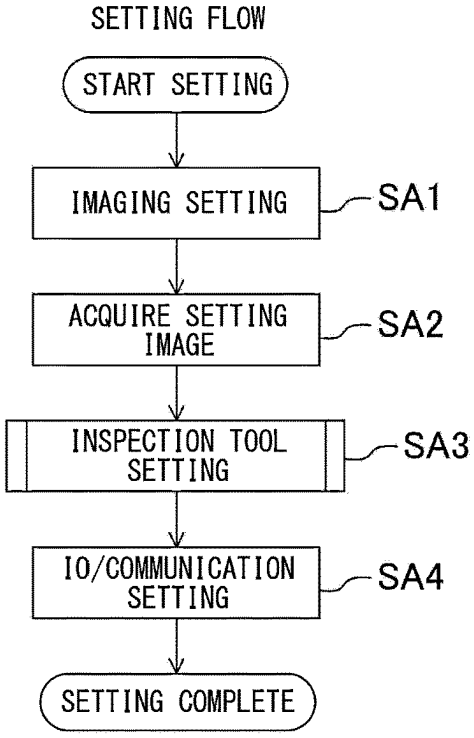

SETTING FLOW
START SETTING
IMAGING SETTING
SA1
ACQUIRE SETTING IMAGE
SA2
INSPECTION TOOL SETTING
SA3
IO/COMMUNICATION SETTING
SA4
SETTING COMPLETE

FIG. 5

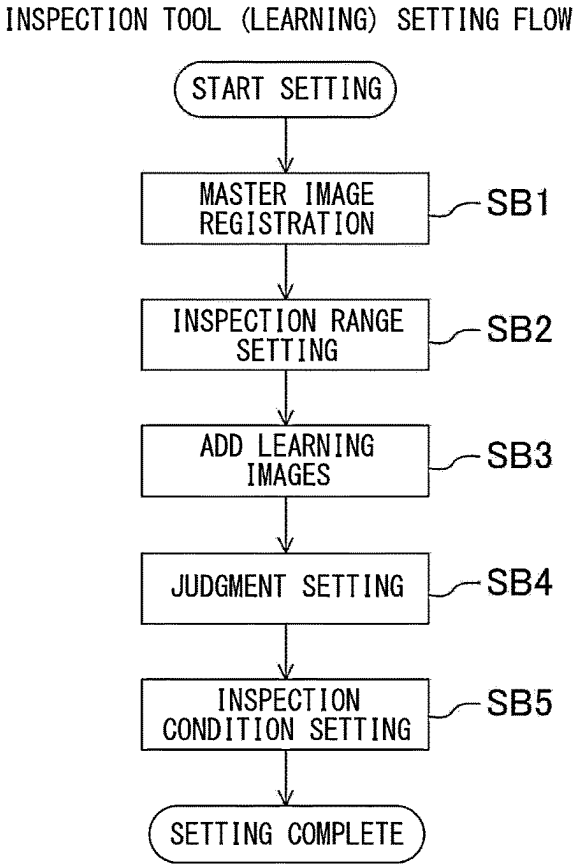
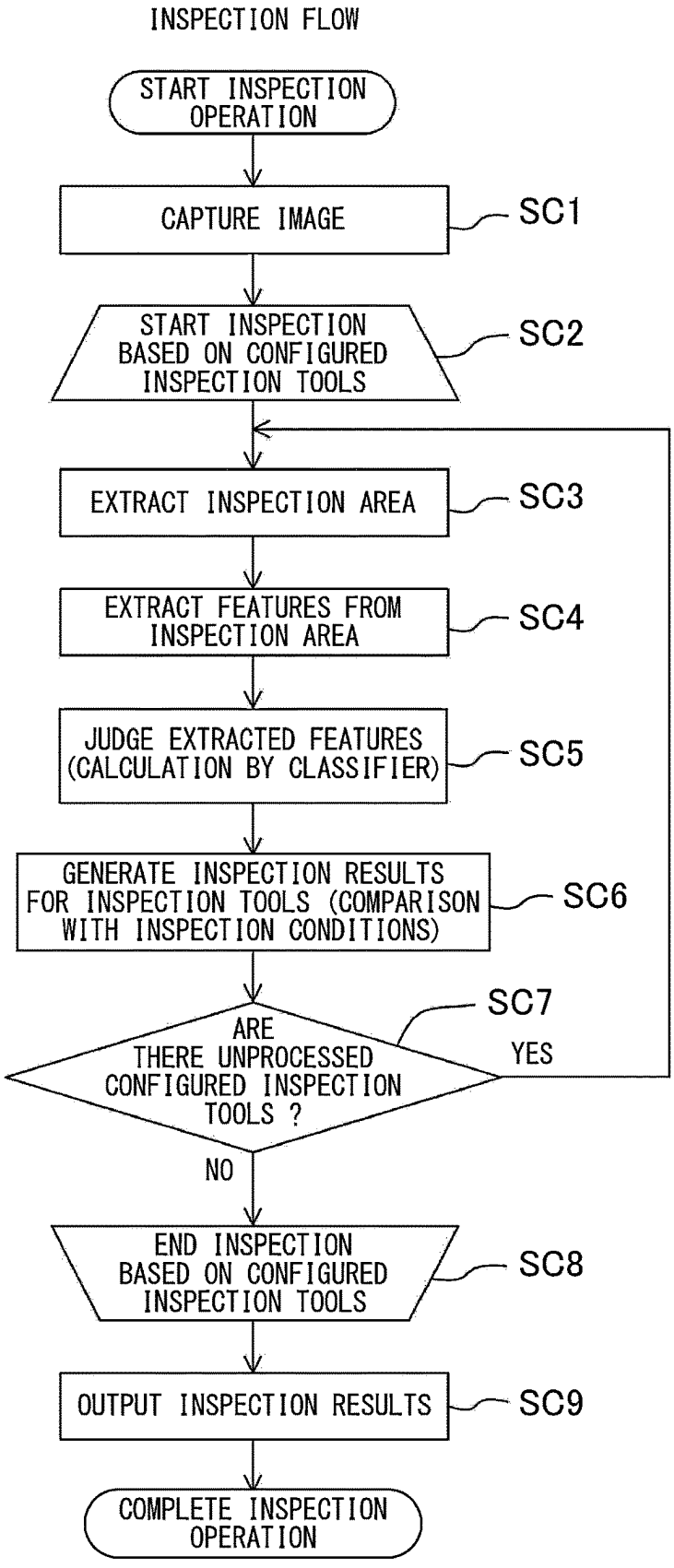

INSPECTION TOOL (LEARNING) SETTING FLOW
START SETTING
MASTER IMAGE REGISTRATION
SB1
INSPECTION RANGE SETTING
SB2
ADD LEARNING IMAGES
SB3
JUDGMENT SETTING
SB4
INSPECTION CONDITION SETTING
SB5
SETTING COMPLETE

FIG. 6


INSPECTION FLOW
START INSPECTION OPERATION
CAPTURE IMAGE
SC1
START INSPECTION BASED ON CONFIGURED INSPECTION TOOLS
SC2
EXTRACT INSPECTION AREA
SC3
EXTRACT FEATURES FROM INSPECTION AREA
SC4
JUDGE EXTRACTED FEATURES (CALCULATION BY CLASSIFIER)
SC5
GENERATE INSPECTION RESULTS FOR INSPECTION TOOLS (COMPARISON WITH INSPECTION CONDITIONS)
SC6
SC7
ARE THERE UNPROCESSED CONFIGURED INSPECTION TOOLS ?
YES
NO
END INSPECTION BASED ON CONFIGURED INSPECTION TOOLS
SC8
OUTPUT INSPECTION RESULTS
SC9
COMPLETE INSPECTION OPERATION

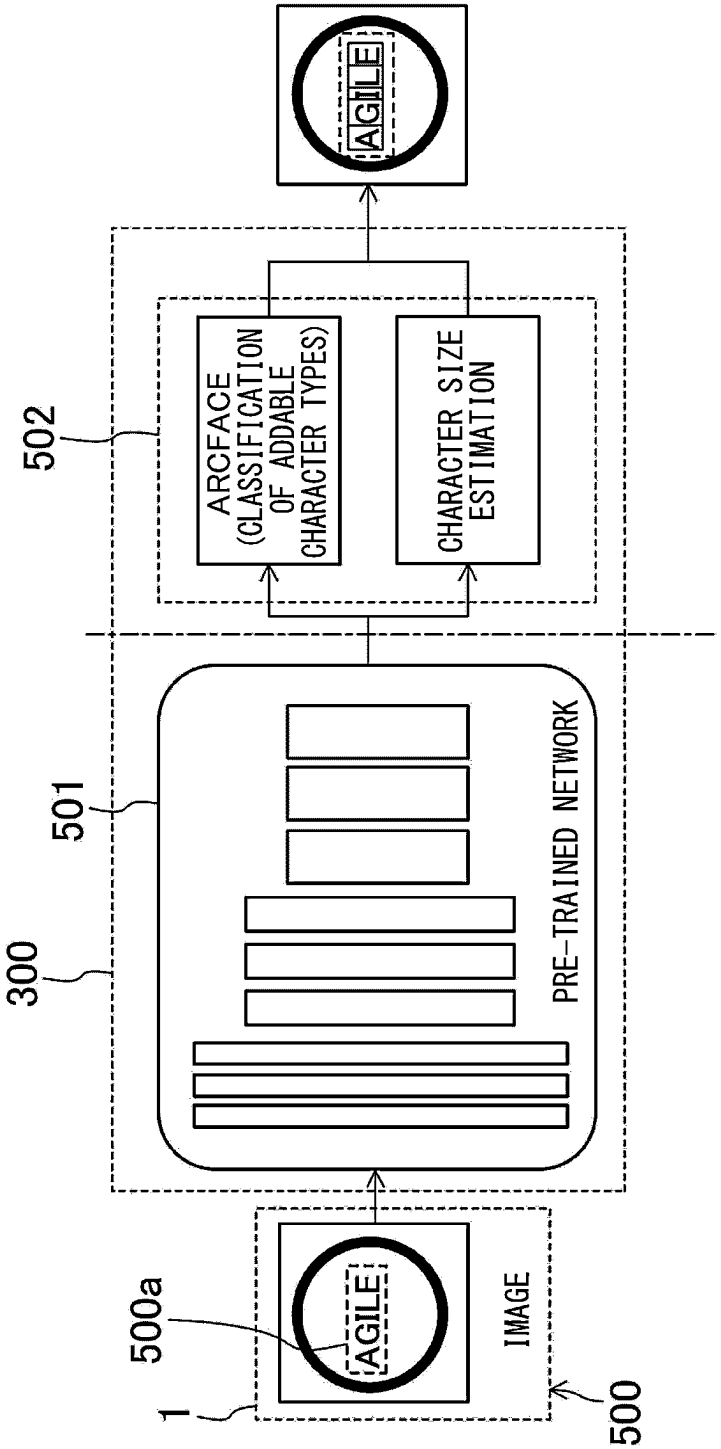

AGILE
502
ARCFACE
(CLASSIFICATION
OF ADDABLE
CHARACTER TYPES)
CHARACTER SIZE
ESTIMATION
501
300
PRE-TRAINED NETWORK
AGILE
500a
1
IMAGE
500

FIG. 7

FIG. 8

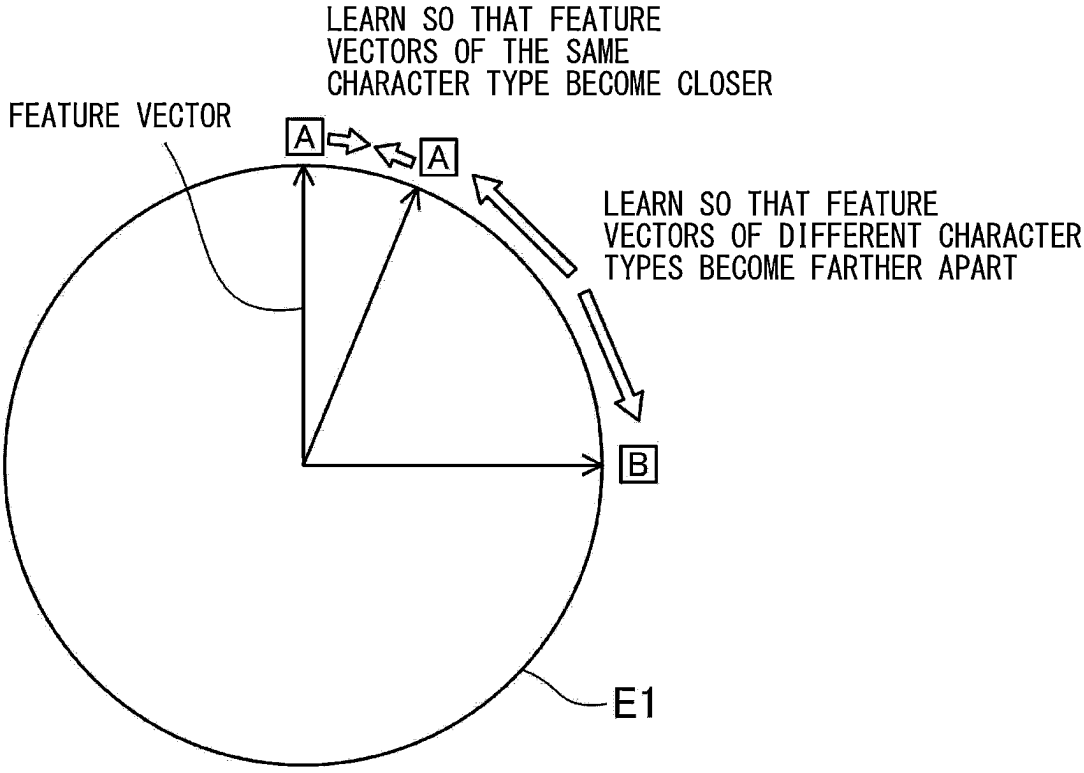

LEARN SO THAT FEATURE VECTORS OF THE SAME CHARACTER TYPE BECOME CLOSER
FEATURE VECTOR
A
A
LEARN SO THAT FEATURE VECTORS OF DIFFERENT CHARACTER TYPES BECOME FARTHER APART
B
E1

FIG. 9

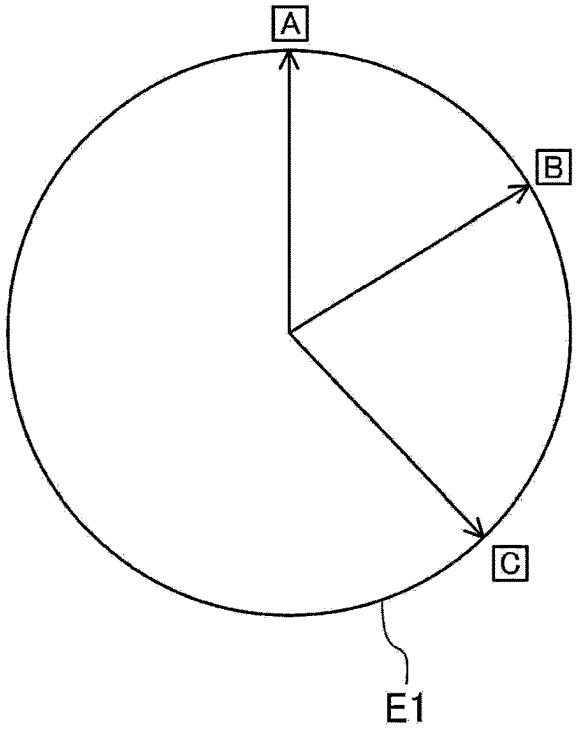


FIG. 10

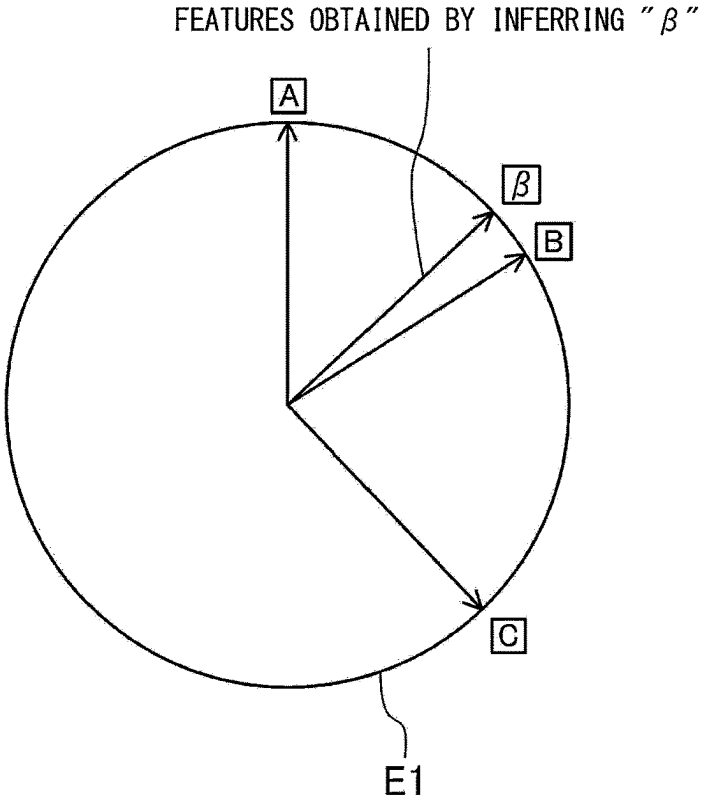


FIG. 11

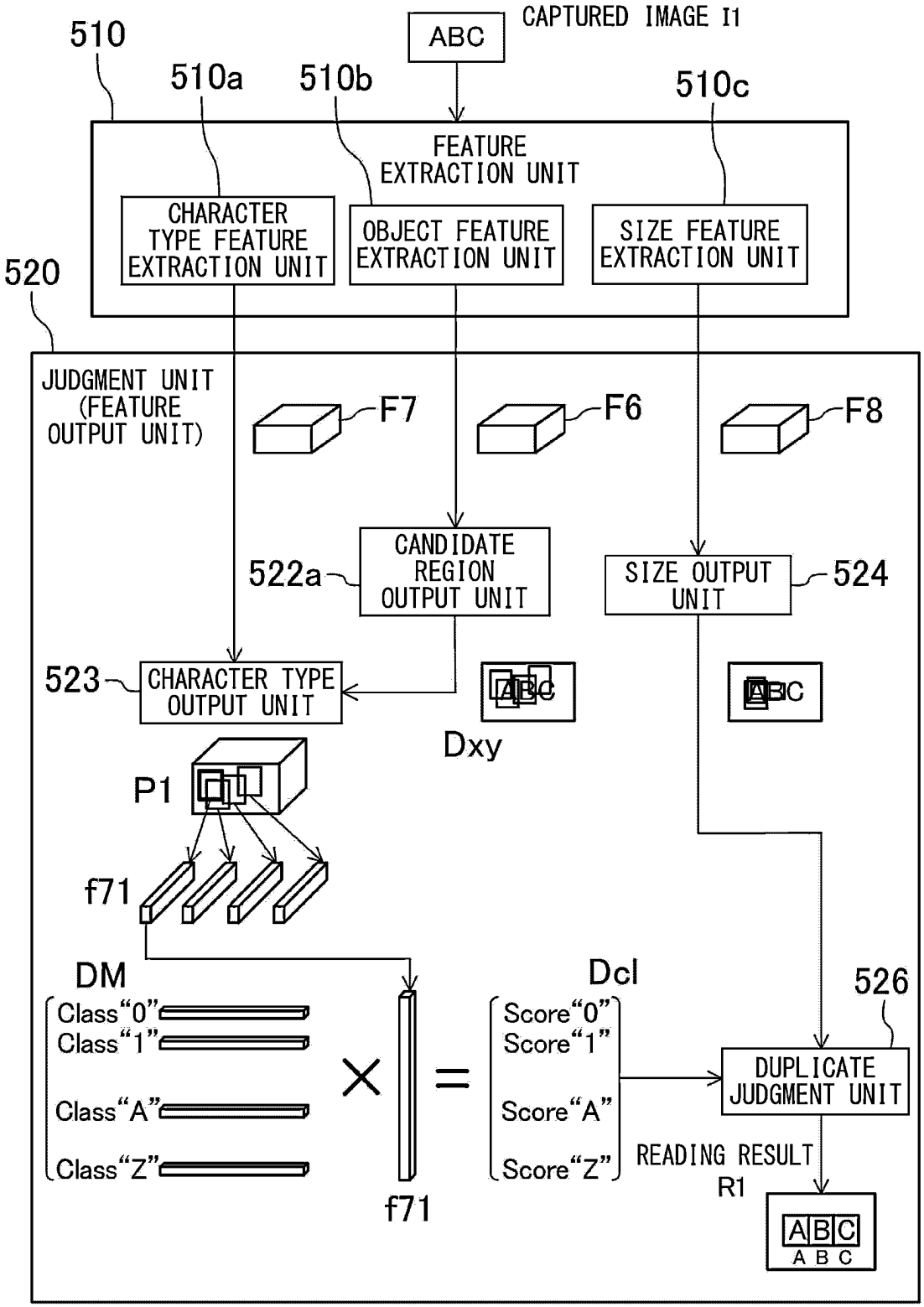

510
510a
510b
510c
ABC
CAPTURED IMAGE I1
FEATURE EXTRACTION UNIT
CHARACTER TYPE FEATURE EXTRACTION UNIT
OBJECT FEATURE EXTRACTION UNIT
SIZE FEATURE EXTRACTION UNIT
520
JUDGMENT UNIT (FEATURE OUTPUT UNIT)
F7
F6
F8
522a
CANDIDATE REGION OUTPUT UNIT
SIZE OUTPUT UNIT
524
523
CHARACTER TYPE OUTPUT UNIT
Dxy
P1
f71
DM
Class"0"
Class"1"
Class"A"
Class"Z"
f71
Dcl
Score"0"
Score"1"
Score"A"
Score"Z"
526
DUPLICATE JUDGMENT UNIT
READING RESULT R1
A B C

FIG. 12

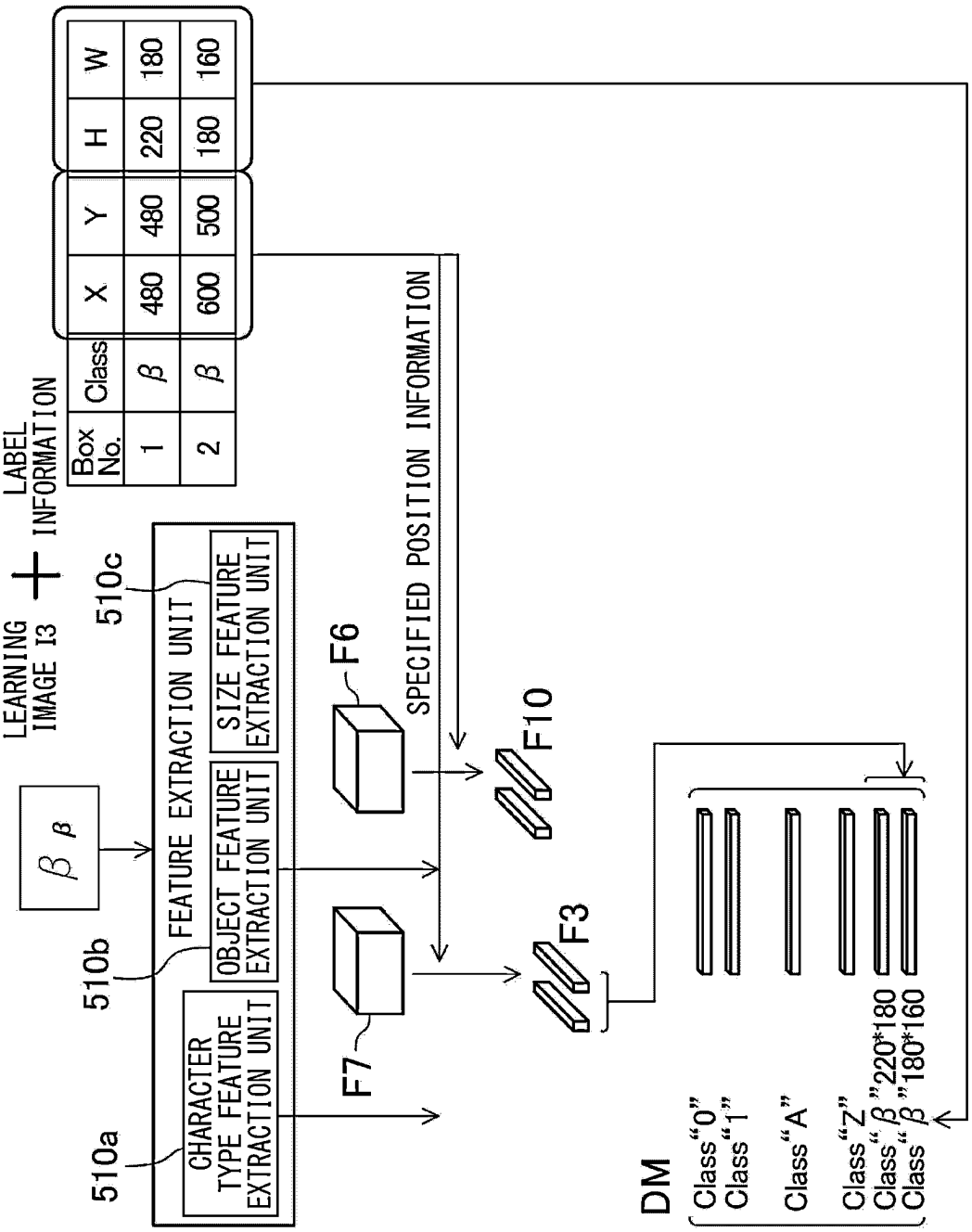
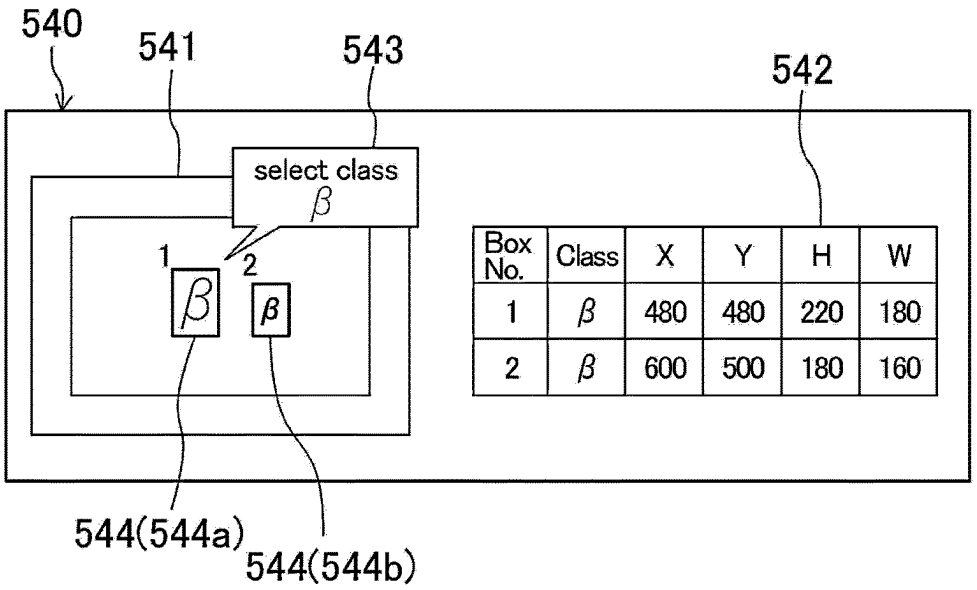

LEARNING IMAGE I3
LABEL INFORMATION
Box No. | Class | X | Y | H | W
1 | β | 480 | 480 | 220 | 180
2 | β | 600 | 500 | 180 | 160
510a
CHARACTER TYPE FEATURE EXTRACTION UNIT
510b
OBJECT FEATURE EXTRACTION UNIT
510c
SIZE FEATURE EXTRACTION UNIT
FEATURE EXTRACTION UNIT
SPECIFIED POSITION INFORMATION
F6
F10
F7
F3
DM
Class "0"
Class "1"
Class "A"
Class "Z"
Class "β" 220*180
Class "β" 180*160

FIG. 13



Box No.	Class	X	Y	H	W
1	β	480	480	220	180
2	β	600	500	180	160

FIG. 14

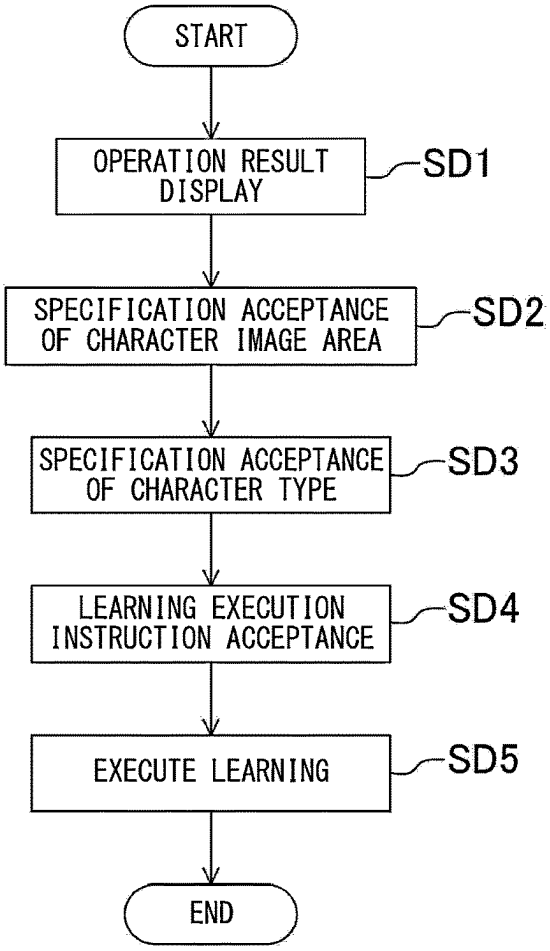


FIG. 15

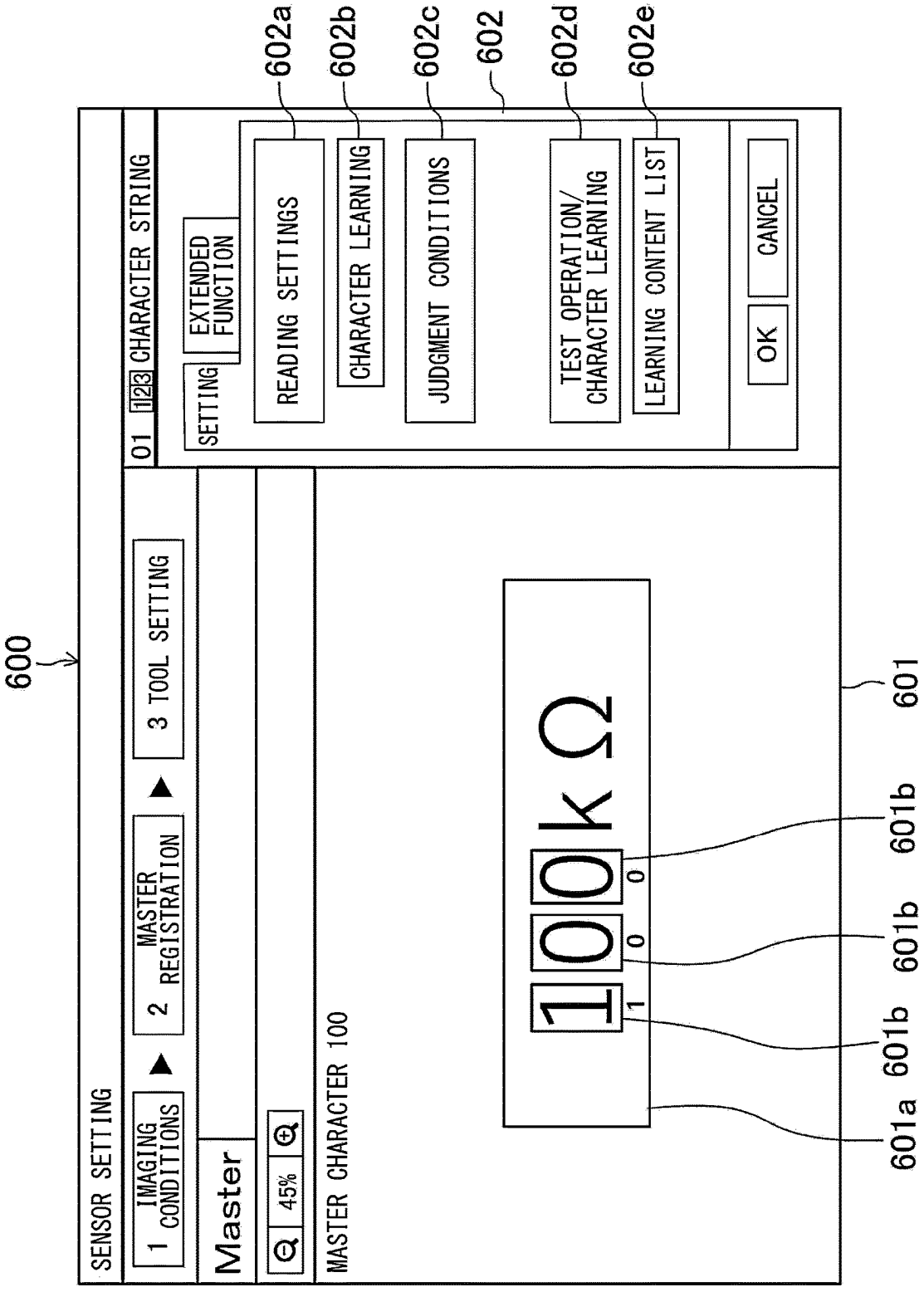
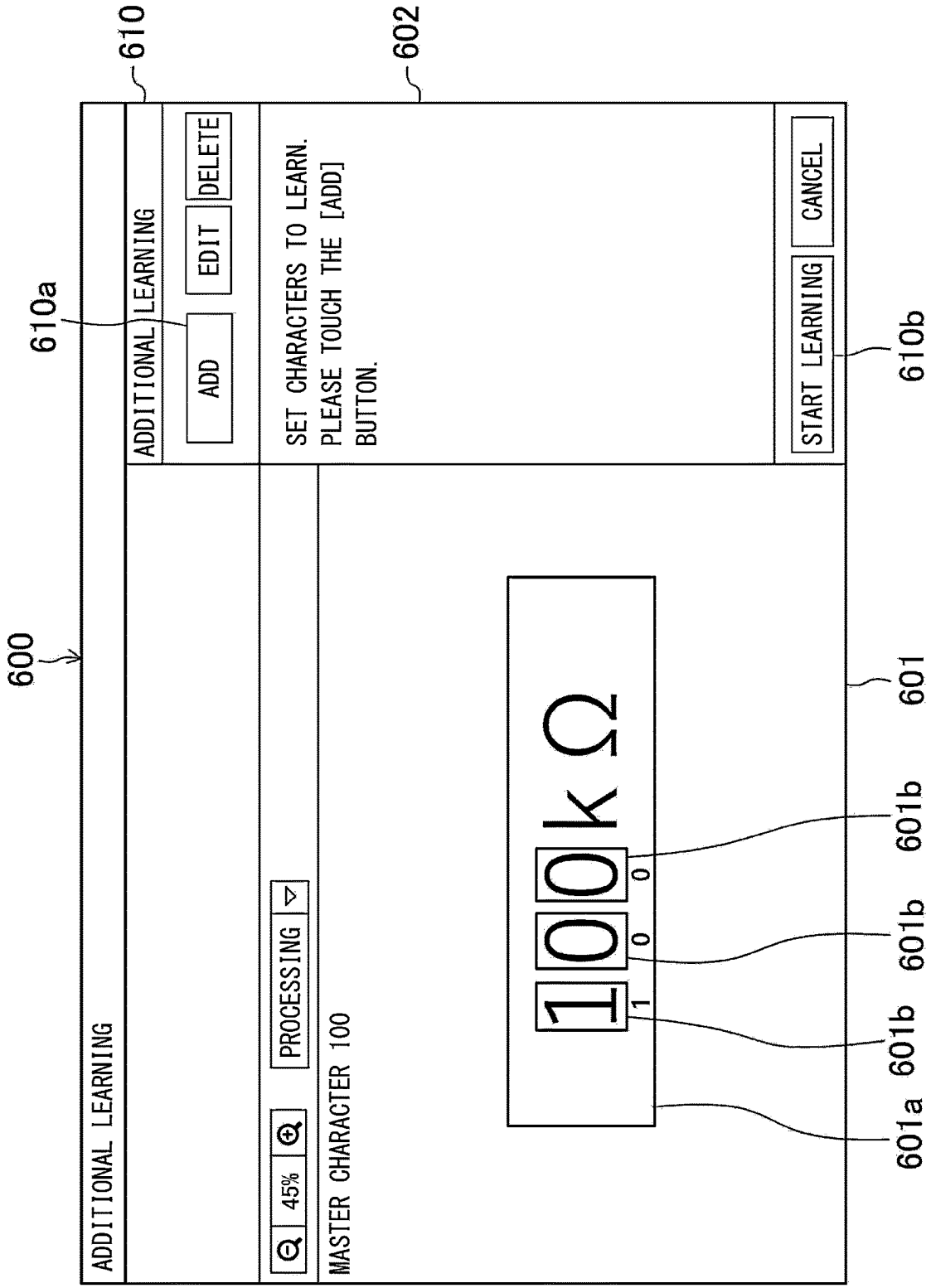

600
SENSOR SETTING
1 IMAGING CONDITIONS
2 MASTER REGISTRATION
3 TOOL SETTING
Master
45%
MASTER CHARACTER 100
100kΩ
01 CHARACTER STRING
SETTING
EXTENDED FUNCTION
READING SETTINGS
CHARACTER LEARNING
JUDGMENT CONDITIONS
TEST OPERATION/ CHARACTER LEARNING
LEARNING CONTENT LIST
OK
CANCEL
602a
602b
602c
602
602d
602e
601
601a
601b
601b
601b

FIG. 16


600
610
610a
602
610b
601
601a
601b
601b
601b
ADDITIONAL LEARNING
ADDITIONAL LEARNING
ADD
EDIT
DELETE
SET CHARACTERS TO LEARN.
PLEASE TOUCH THE [ADD]
BUTTON.
START LEARNING
CANCEL
45%
PROCESSING
MASTER CHARACTER 100
100kΩ
1
0
0

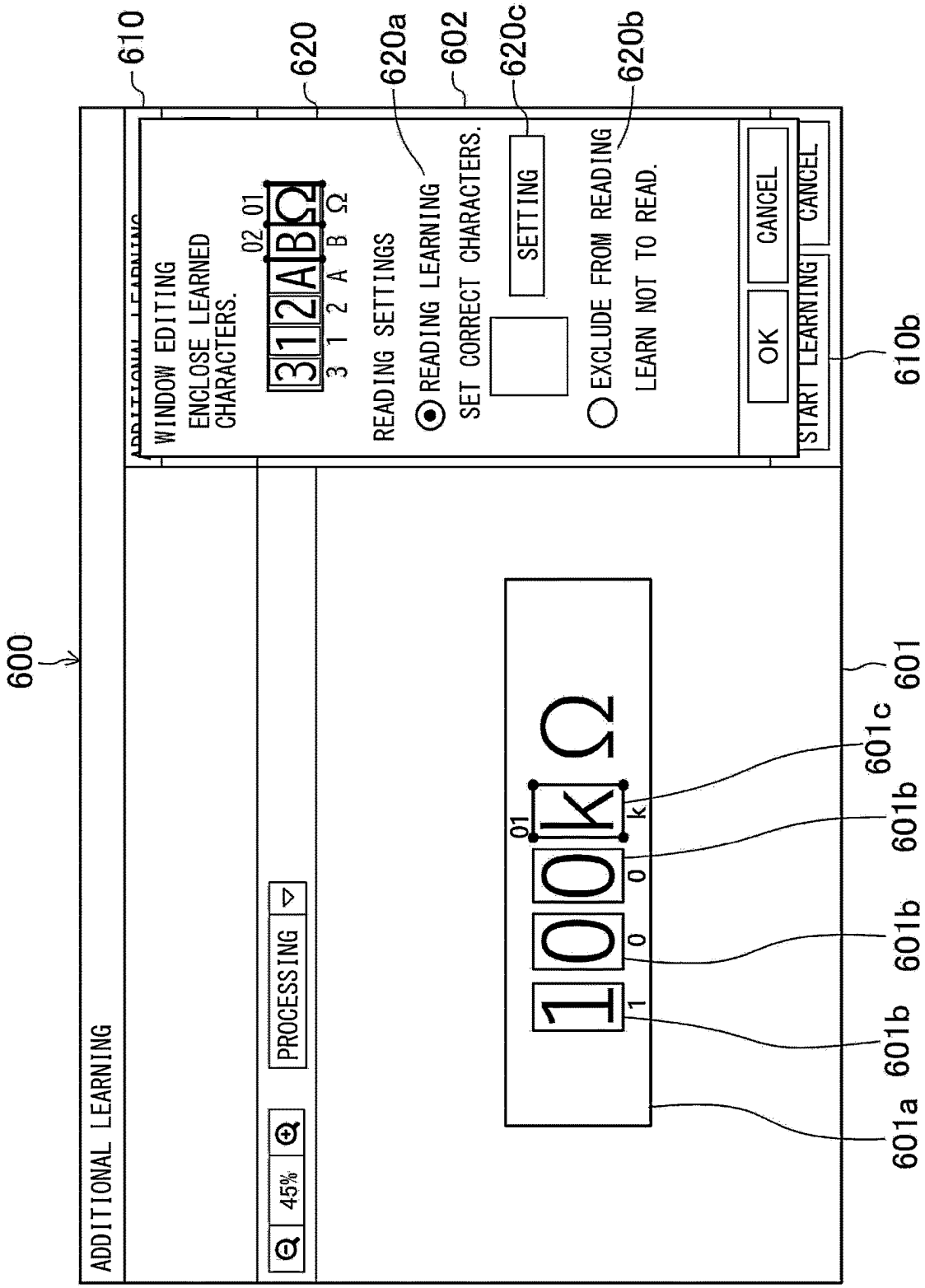

600
610
620
620a
602
620c
620b
610b
601
601c
601b
601b
601b
601a
ADDITIONAL LEARNING
WINDOW EDITING
ENCLOSE LEARNED CHARACTERS.
02 01
3 1 2 A B Ω
READING SETTINGS
READING LEARNING
SET CORRECT CHARACTERS.
SETTING
EXCLUDE FROM READING
LEARN NOT TO READ.
OK
CANCEL
START LEARNING
CANCEL
PROCESSING
45%
01
100kΩ

FIG. 17

FIG. 18

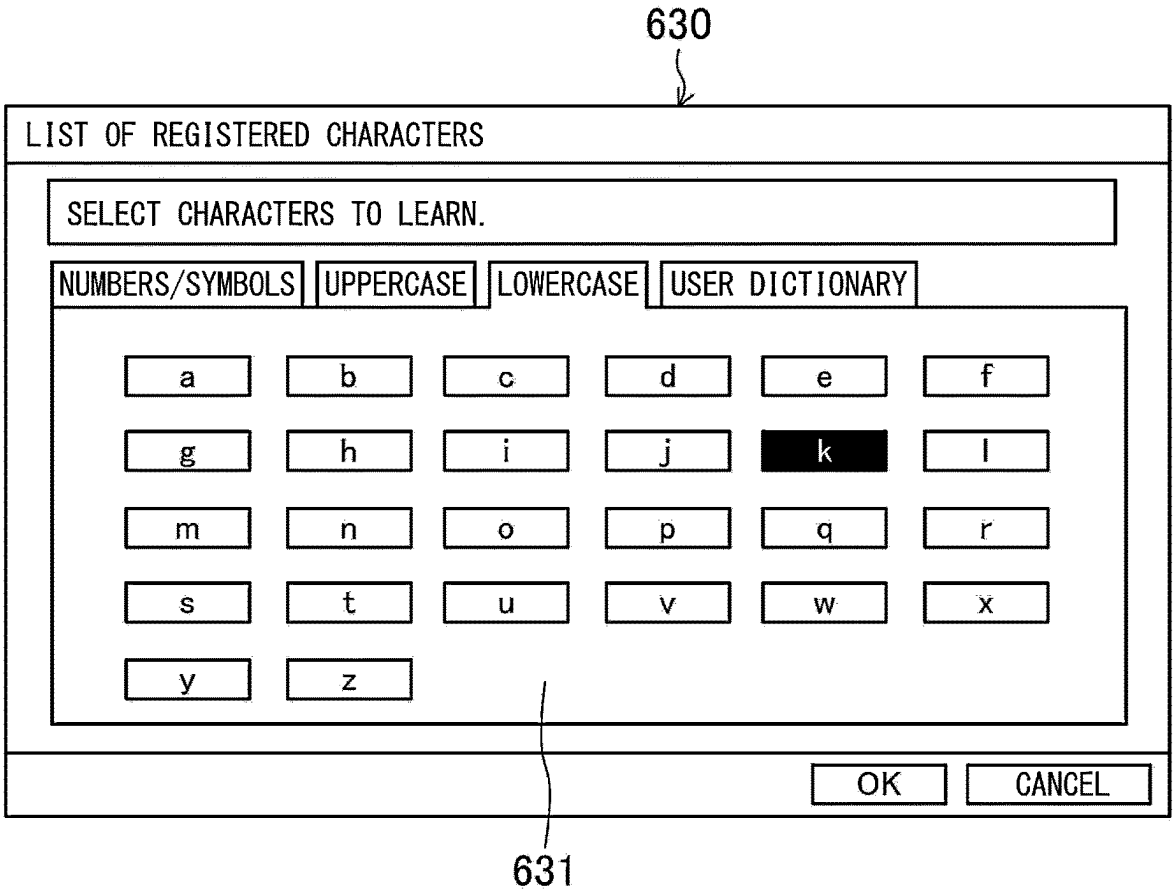

630
LIST OF REGISTERED CHARACTERS
SELECT CHARACTERS TO LEARN.
NUMBERS/SYMBOLS
UPPERCASE
LOWERCASE
USER DICTIONARY
a
b
c
d
e
f
g
h
i
j
k
l
m
n
o
p
q
r
s
t
u
v
w
x
y
z
OK
CANCEL
631

FIG. 19

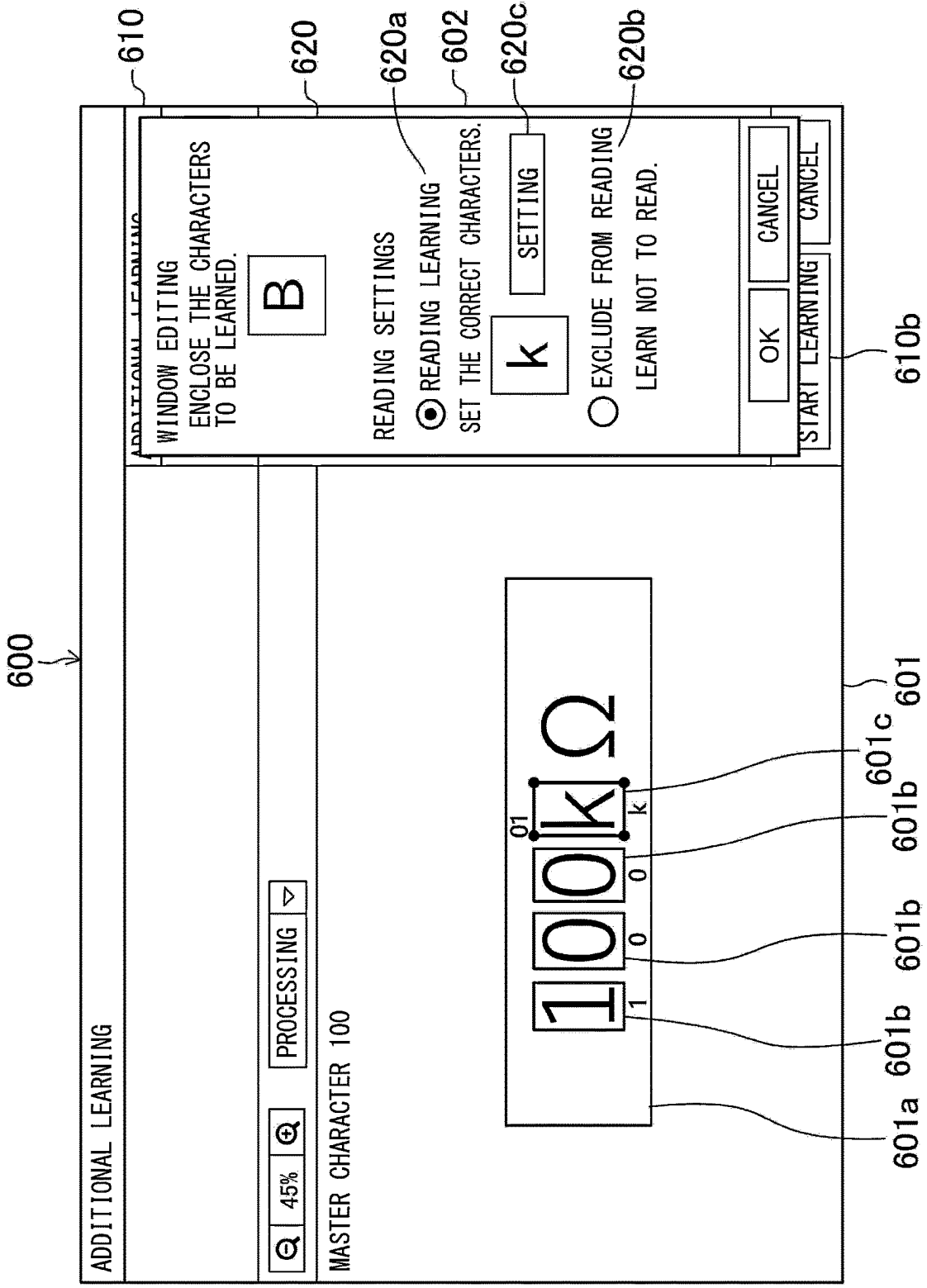

600
610
620
620a
602
620c
620b
610b
601
601c
601b
601b
601b
601a
ADDITIONAL LEARNING
WINDOW EDITING
ENCLOSE THE CHARACTERS TO BE LEARNED.
B
READING SETTINGS
READING LEARNING
SET THE CORRECT CHARACTERS.
k
SETTING
EXCLUDE FROM READING
LEARN NOT TO READ.
OK
CANCEL
START LEARNING
CANCEL
45%
PROCESSING
MASTER CHARACTER 100
100kΩ

FIG. 20

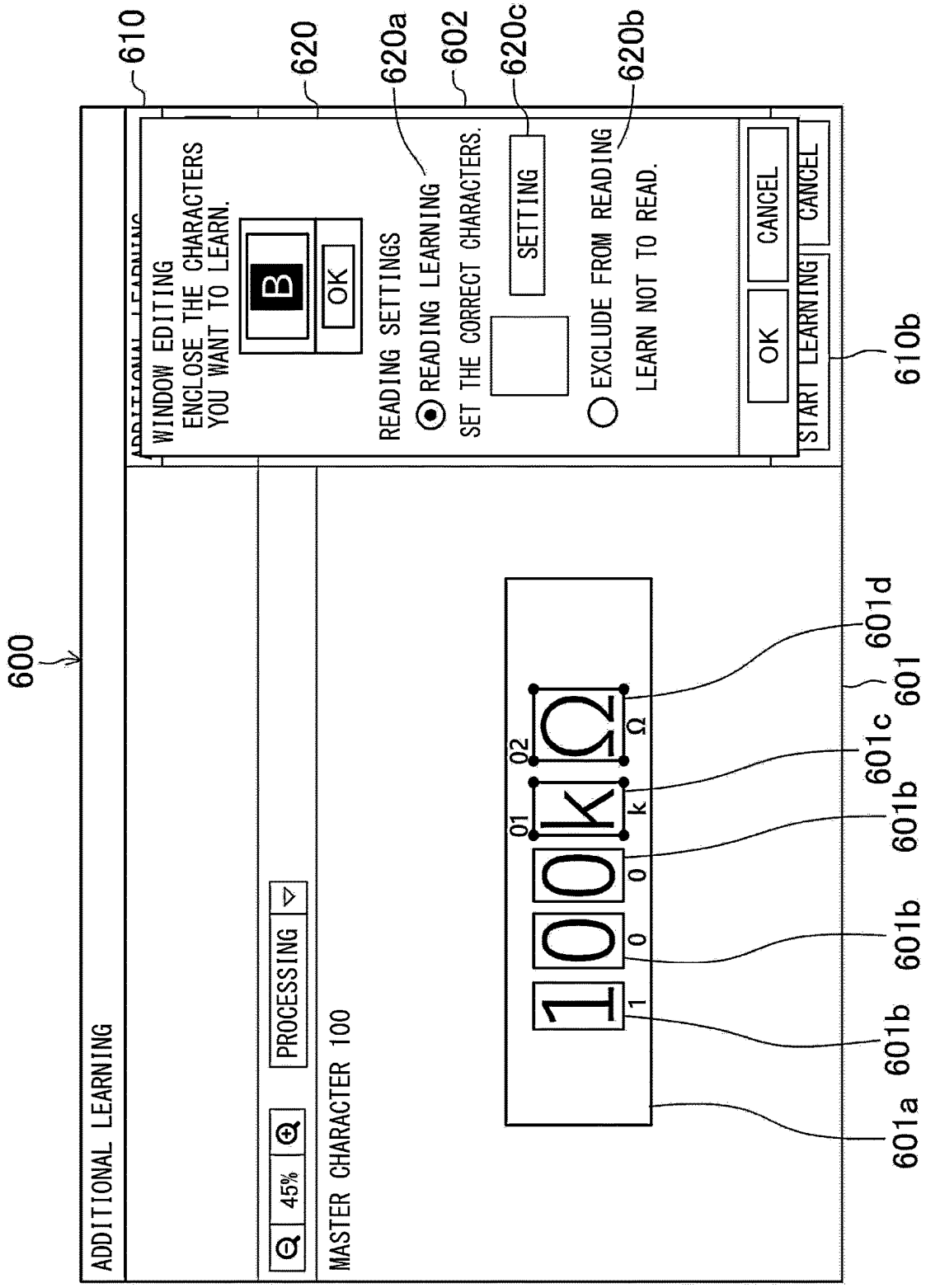

600
610
620
620a
602
620c
620b
610b
601
601d
601c
601b
601b
601b
601a
ADDITIONAL LEARNING
WINDOW EDITING
ENCLOSE THE CHARACTERS YOU WANT TO LEARN.
B
OK
READING SETTINGS
READING LEARNING
SET THE CORRECT CHARACTERS.
SETTING
EXCLUDE FROM READING
LEARN NOT TO READ.
OK
CANCEL
START LEARNING
CANCEL
PROCESSING
45%
MASTER CHARACTER 100
100kΩ

FIG. 21

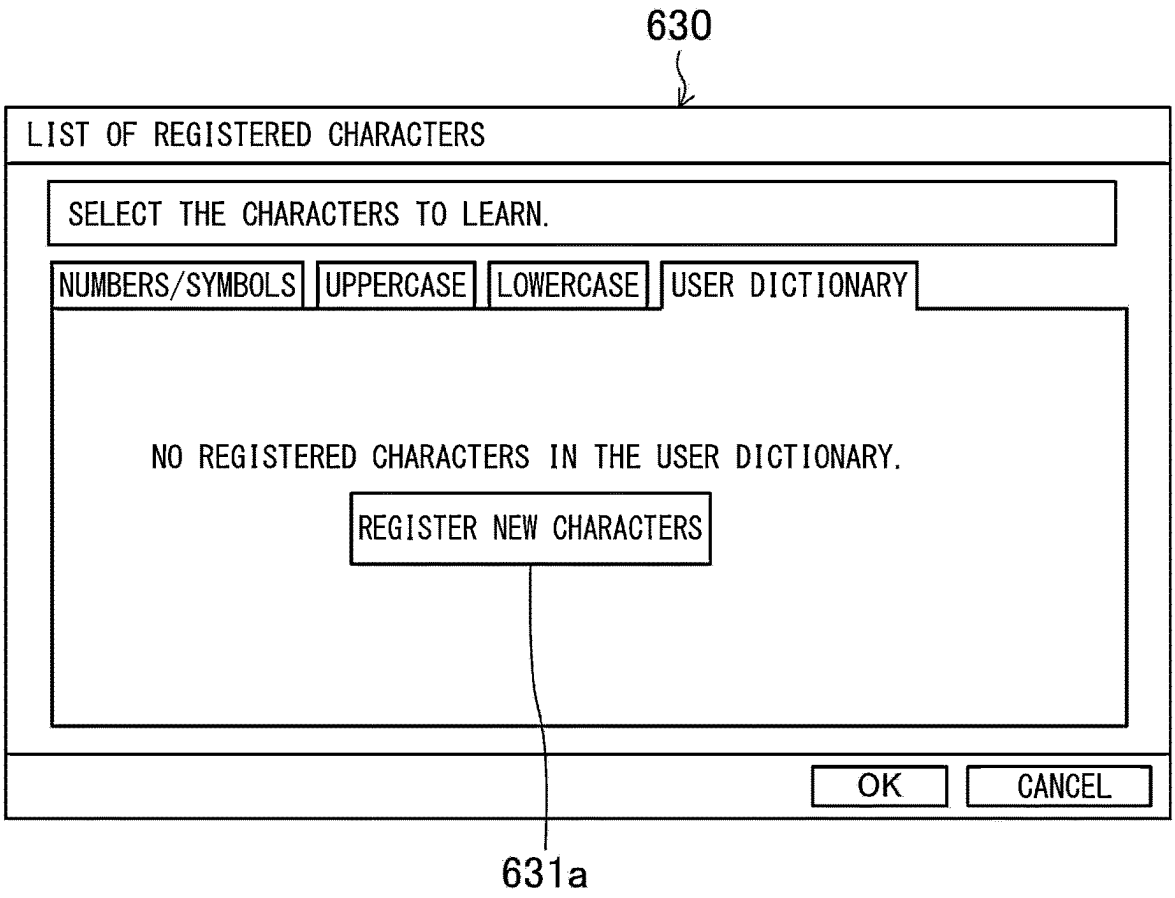

630
LIST OF REGISTERED CHARACTERS
SELECT THE CHARACTERS TO LEARN.
NUMBERS/SYMBOLS
UPPERCASE
LOWERCASE
USER DICTIONARY
NO REGISTERED CHARACTERS IN THE USER DICTIONARY.
REGISTER NEW CHARACTERS
OK
CANCEL
631a

FIG. 22

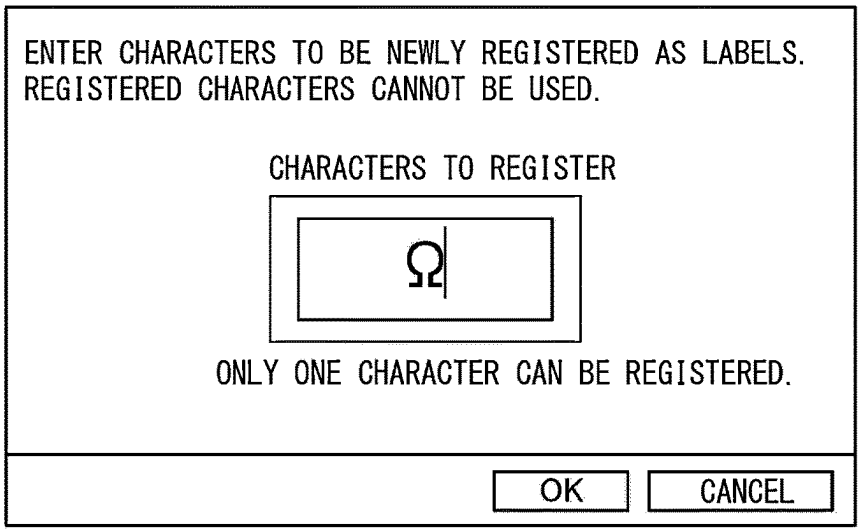

ENTER CHARACTERS TO BE NEWLY REGISTERED AS LABELS.
REGISTERED CHARACTERS CANNOT BE USED.
CHARACTERS TO REGISTER
Ω
ONLY ONE CHARACTER CAN BE REGISTERED.
OK
CANCEL

FIG. 23

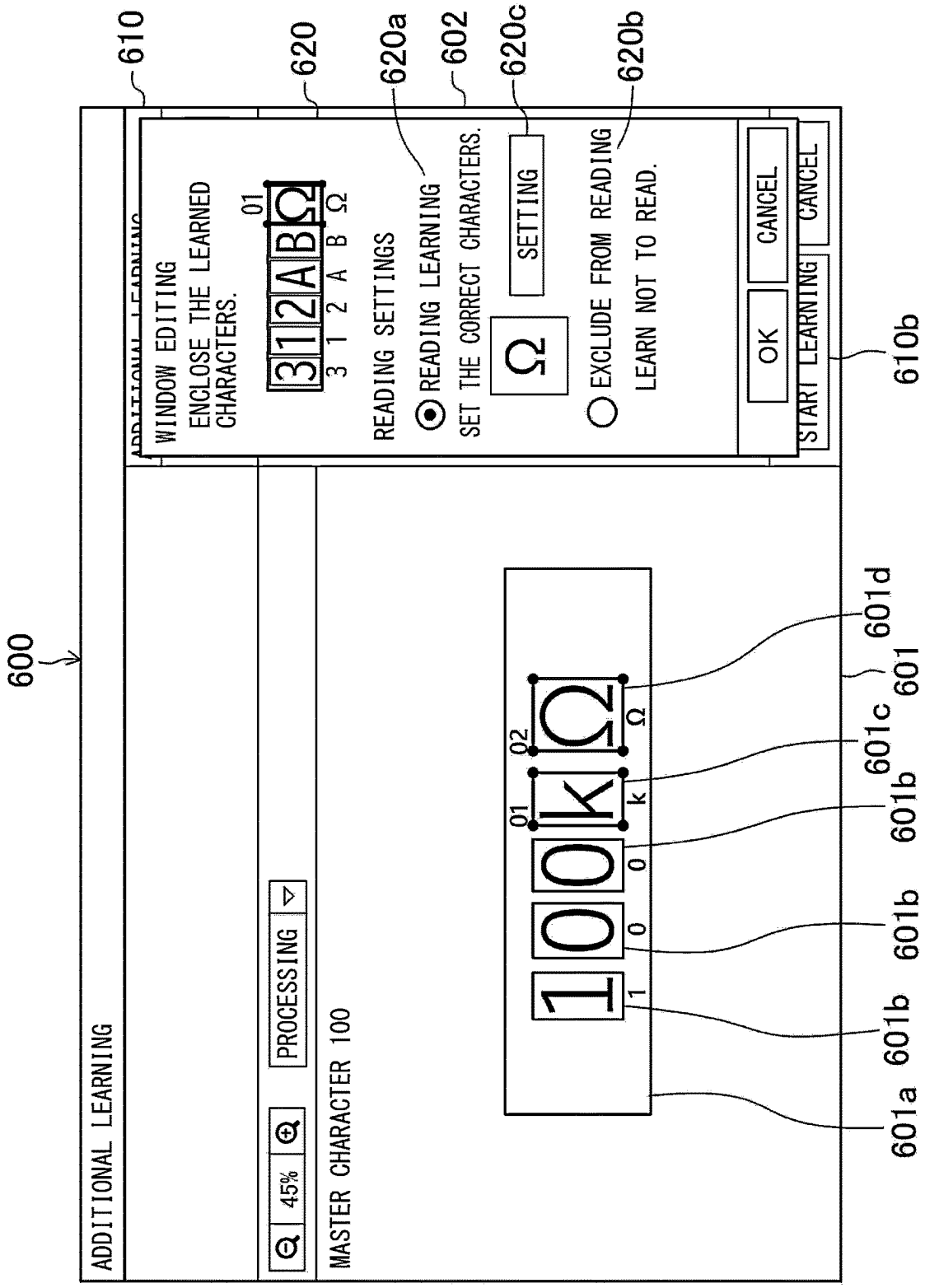

600
610
620
620a
602
620c
620b
610b
601
601a
601b
601c
601d
ADDITIONAL LEARNING
WINDOW EDITING
ENCLOSE THE LEARNED CHARACTERS.
READING SETTINGS
READING LEARNING
SET THE CORRECT CHARACTERS.
SETTING
EXCLUDE FROM READING
LEARN NOT TO READ.
OK
CANCEL
START LEARNING
CANCEL
PROCESSING
45%
MASTER CHARACTER 100

FIG. 24

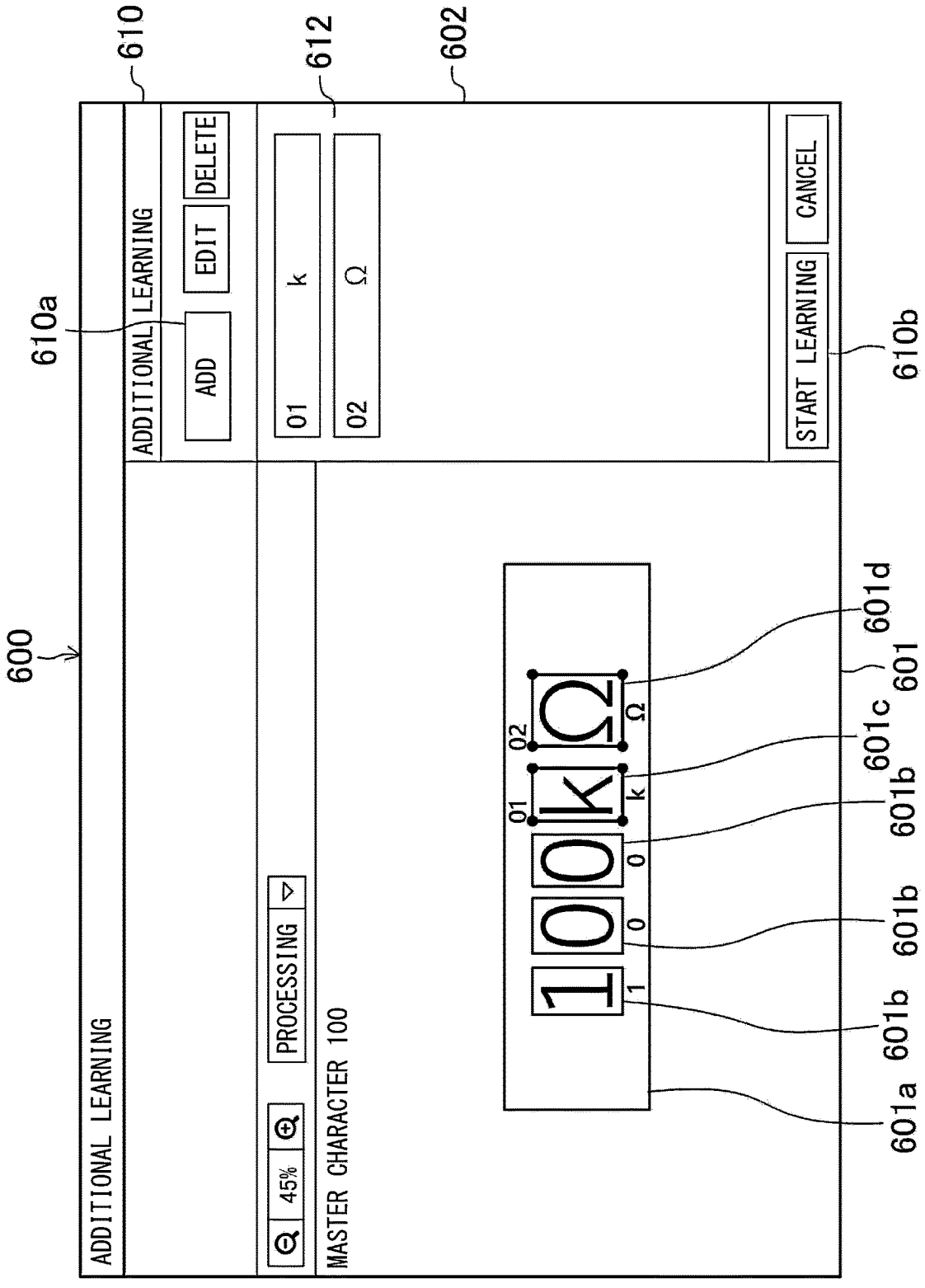

600
610
610a
612
602
610b
ADDITIONAL LEARNING
ADDITIONAL LEARNING
ADD
EDIT
DELETE
01
k
02
Ω
START LEARNING
CANCEL
PROCESSING
MASTER CHARACTER 100
45%
601
601a
601b
601c
601d

FIG. 25

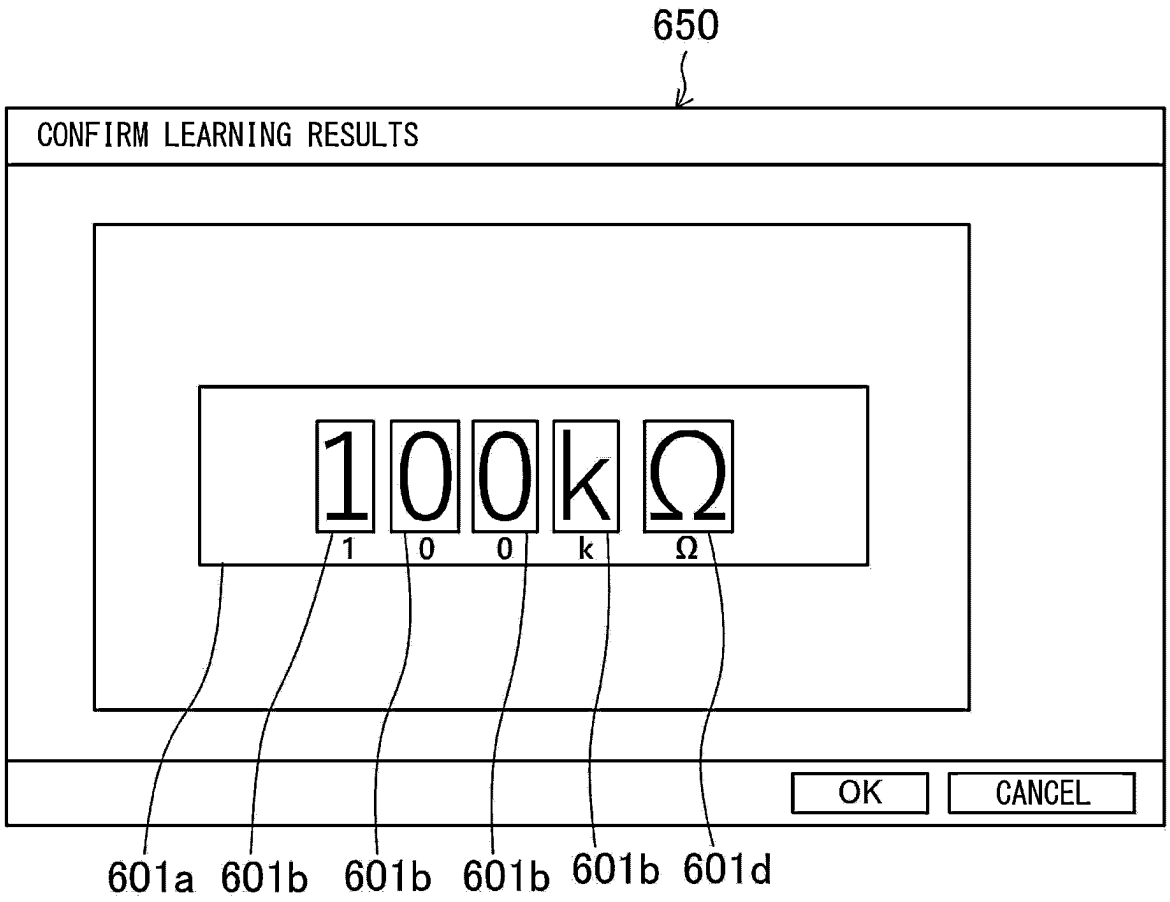

650
CONFIRM LEARNING RESULTS
1 0 0 k Ω
1 0 0 k Ω
OK
CANCEL
601a 601b 601b 601b 601b 601d

FIG. 26

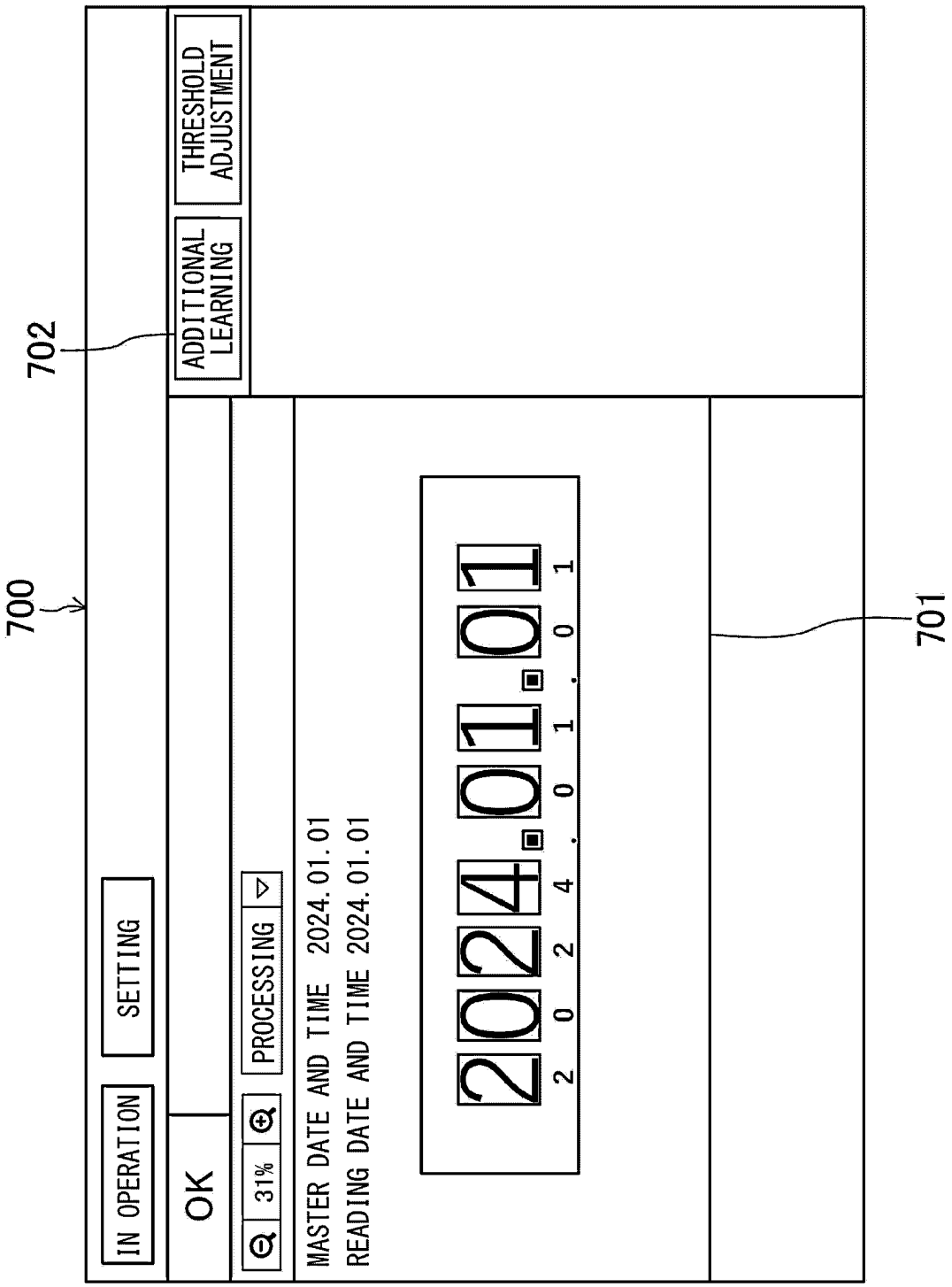

700
702
701
IN OPERATION
SETTING
ADDITIONAL LEARNING
THRESHOLD ADJUSTMENT
OK
31%
PROCESSING
MASTER DATE AND TIME 2024.01.01
READING DATE AND TIME 2024.01.01
2024.01.01
2024.01.01

FIG. 27

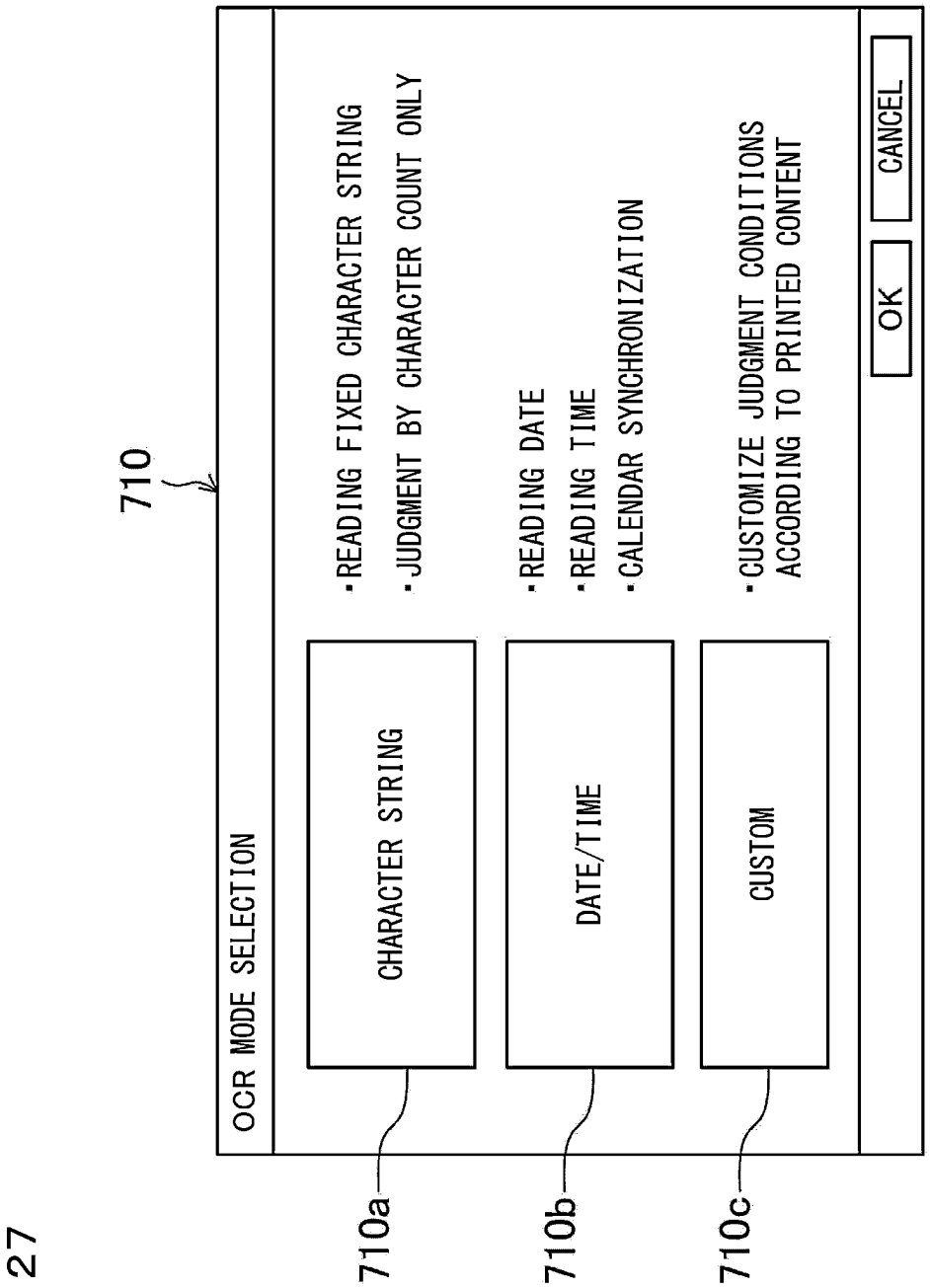

710
OCR MODE SELECTION
CHARACTER STRING
DATE/TIME
CUSTOM
・READING FIXED CHARACTER STRING
・JUDGMENT BY CHARACTER COUNT ONLY
・READING DATE
・READING TIME
・CALENDAR SYNCHRONIZATION
・CUSTOMIZE JUDGMENT CONDITIONS ACCORDING TO PRINTED CONTENT
OK
CANCEL
710a
710b
710c

FIG. 28

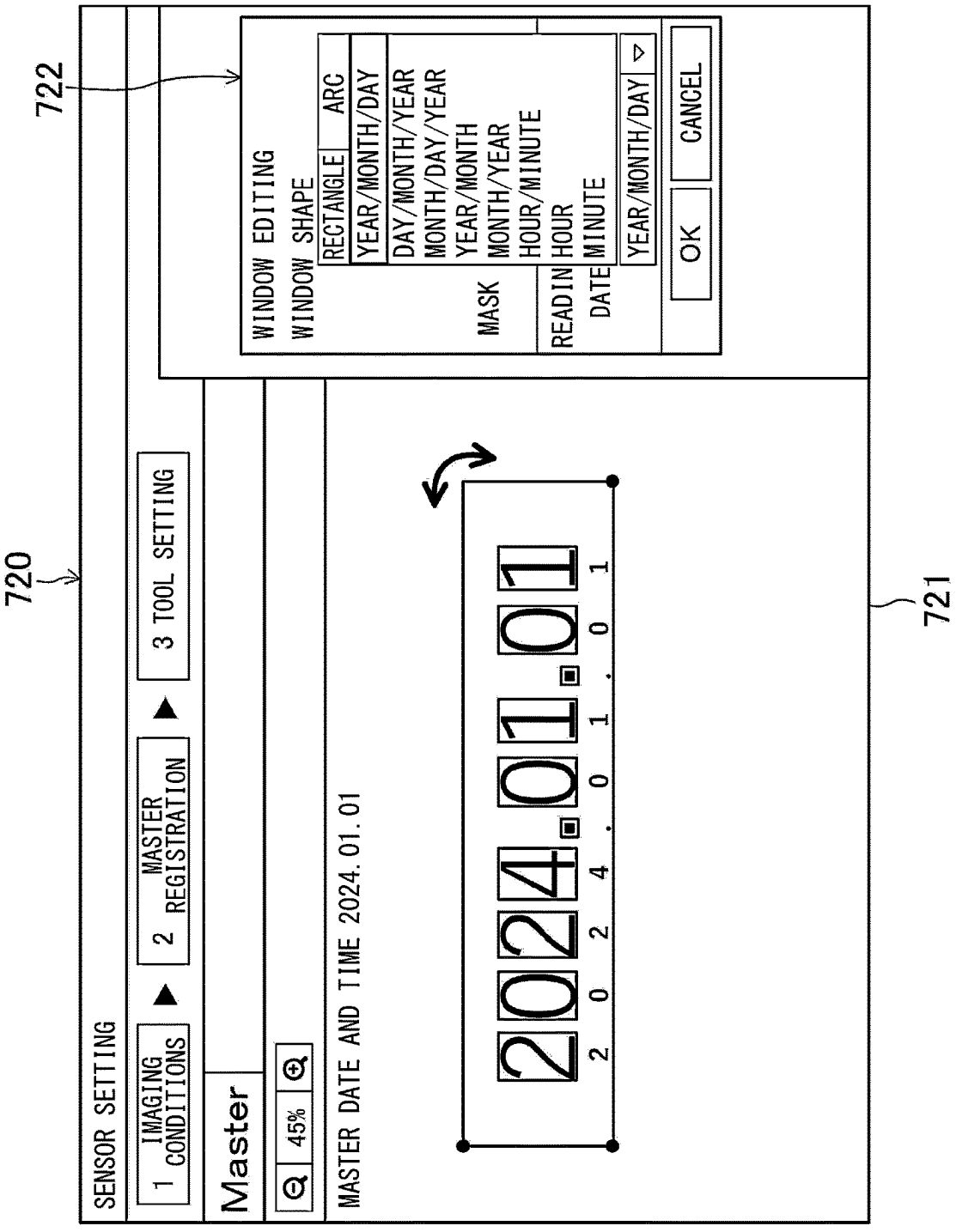

720
721
722
SENSOR SETTING
1 IMAGING CONDITIONS
2 MASTER REGISTRATION
3 TOOL SETTING
Master
45%
MASTER DATE AND TIME 2024.01.01
2024.01.01
2024.01.01
WINDOW EDITING
WINDOW SHAPE
RECTANGLE
ARC
MASK
YEAR/MONTH/DAY
DAY/MONTH/YEAR
MONTH/DAY/YEAR
YEAR/MONTH
MONTH/YEAR
HOUR/MINUTE
READIN
DATE
HOUR
MINUTE
YEAR/MONTH/DAY
OK
CANCEL

FIG. 29

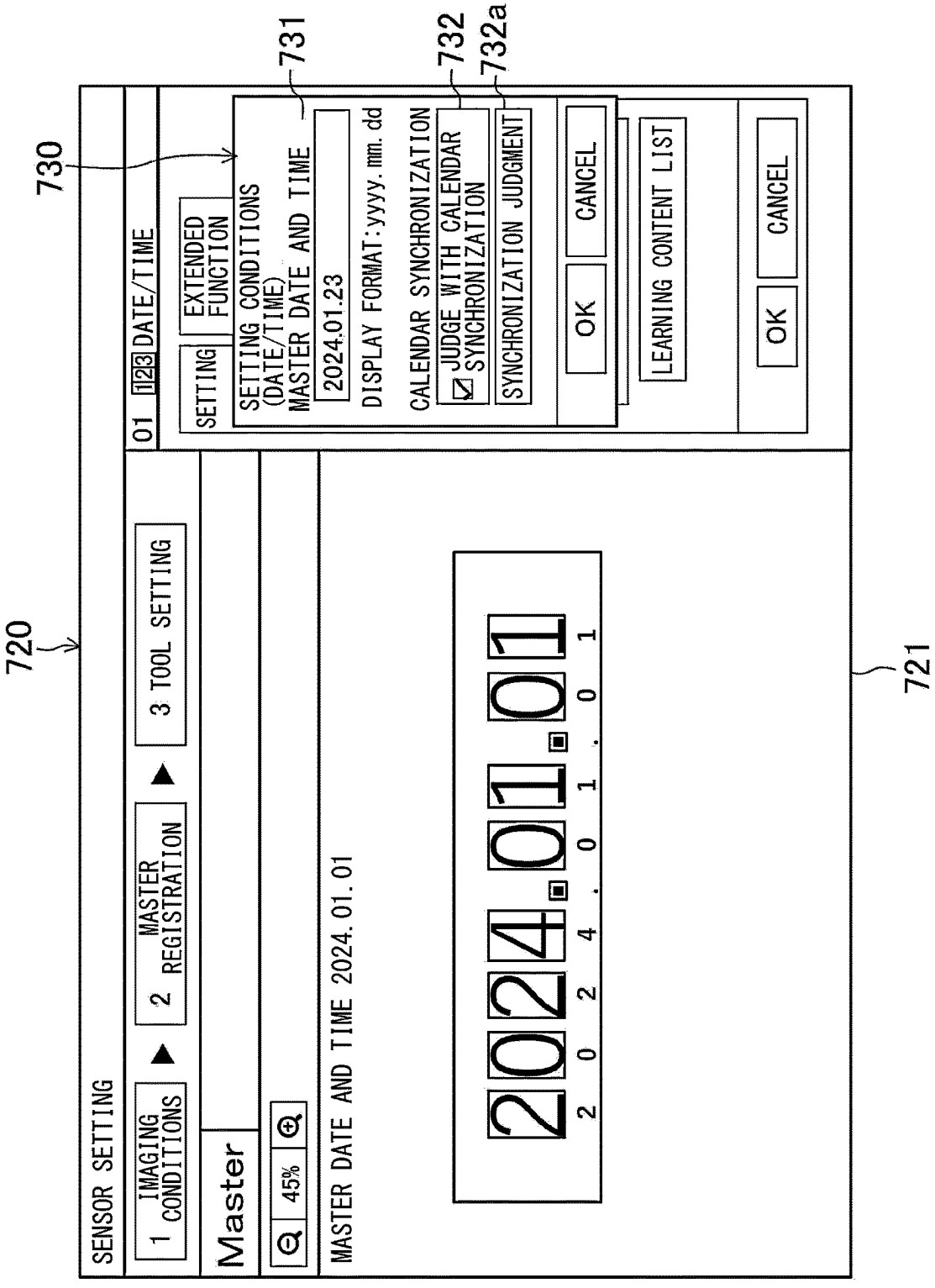

720
730
731
732
732a
721
SENSOR SETTING
1 IMAGING CONDITIONS
2 MASTER REGISTRATION
3 TOOL SETTING
Master
45%
MASTER DATE AND TIME 2024.01.01
01 DATE/TIME
SETTING
EXTENDED FUNCTION
SETTING CONDITIONS (DATE/TIME)
MASTER DATE AND TIME
2024.01.23
DISPLAY FORMAT:yyyy.mm.dd
CALENDAR SYNCHRONIZATION
JUDGE WITH CALENDAR SYNCHRONIZATION
SYNCHRONIZATION JUDGMENT
OK
CANCEL
LEARNING CONTENT LIST
OK
CANCEL
2024.01.01
2024.01.01

FIG. 30

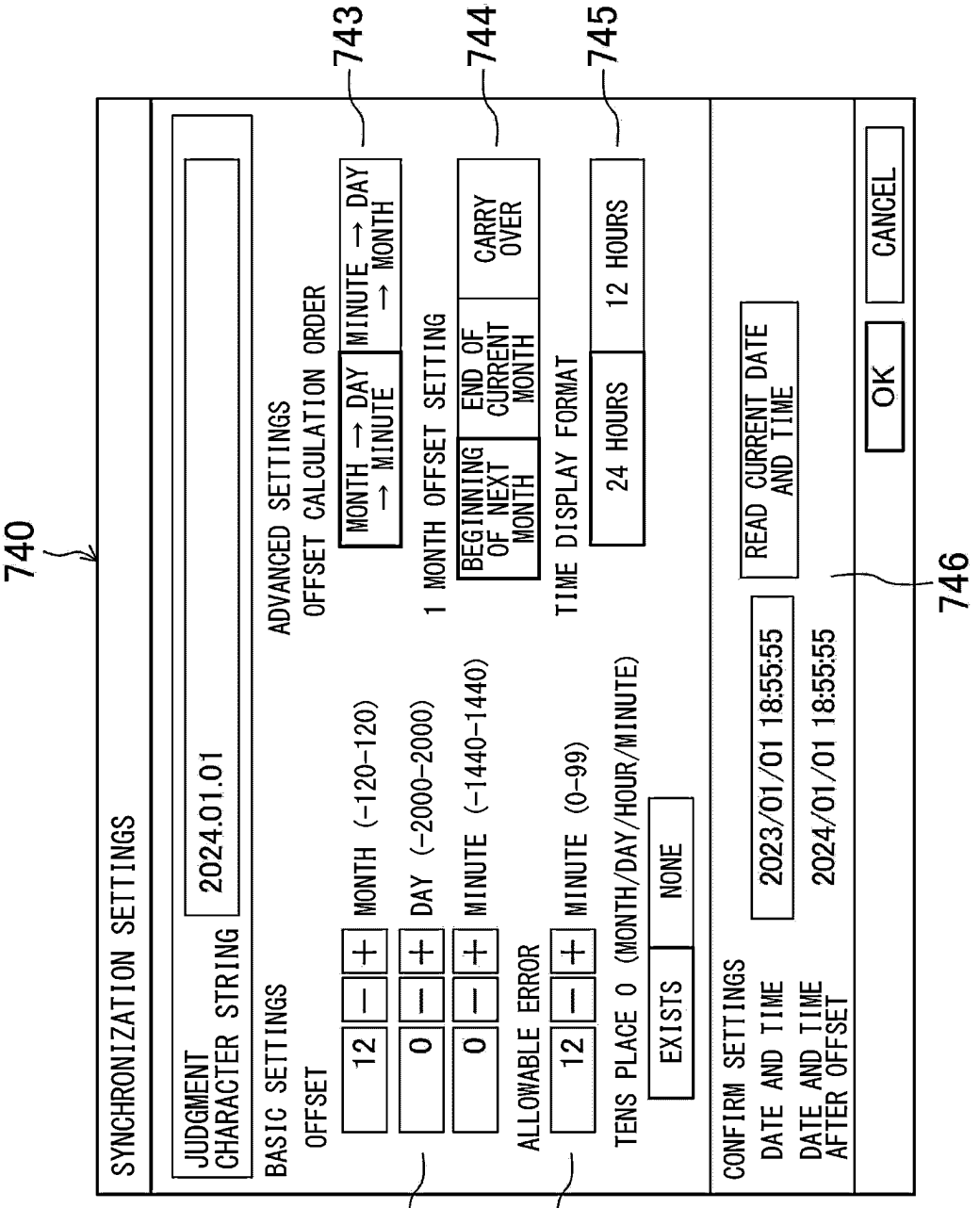

740
SYNCHRONIZATION SETTINGS
JUDGMENT CHARACTER STRING
2024.01.01
BASIC SETTINGS
OFFSET
12 — + MONTH (-120-120)
0 — + DAY (-2000-2000)
0 — + MINUTE (-1440-1440)
ALLOWABLE ERROR
12 — + MINUTE (0-99)
TENS PLACE 0 (MONTH/DAY/HOUR/MINUTE)
EXISTS
NONE
ADVANCED SETTINGS
OFFSET CALCULATION ORDER
MONTH → DAY → MINUTE
MINUTE → DAY → MONTH
1 MONTH OFFSET SETTING
BEGINNING OF NEXT MONTH
END OF CURRENT MONTH
CARRY OVER
TIME DISPLAY FORMAT
24 HOURS
12 HOURS
CONFIRM SETTINGS
DATE AND TIME
2023/01/01 18:55:55
READ CURRENT DATE AND TIME
DATE AND TIME AFTER OFFSET
2024/01/01 18:55:55
OK
CANCEL
741
742
743
744
745
746

FIG. 31

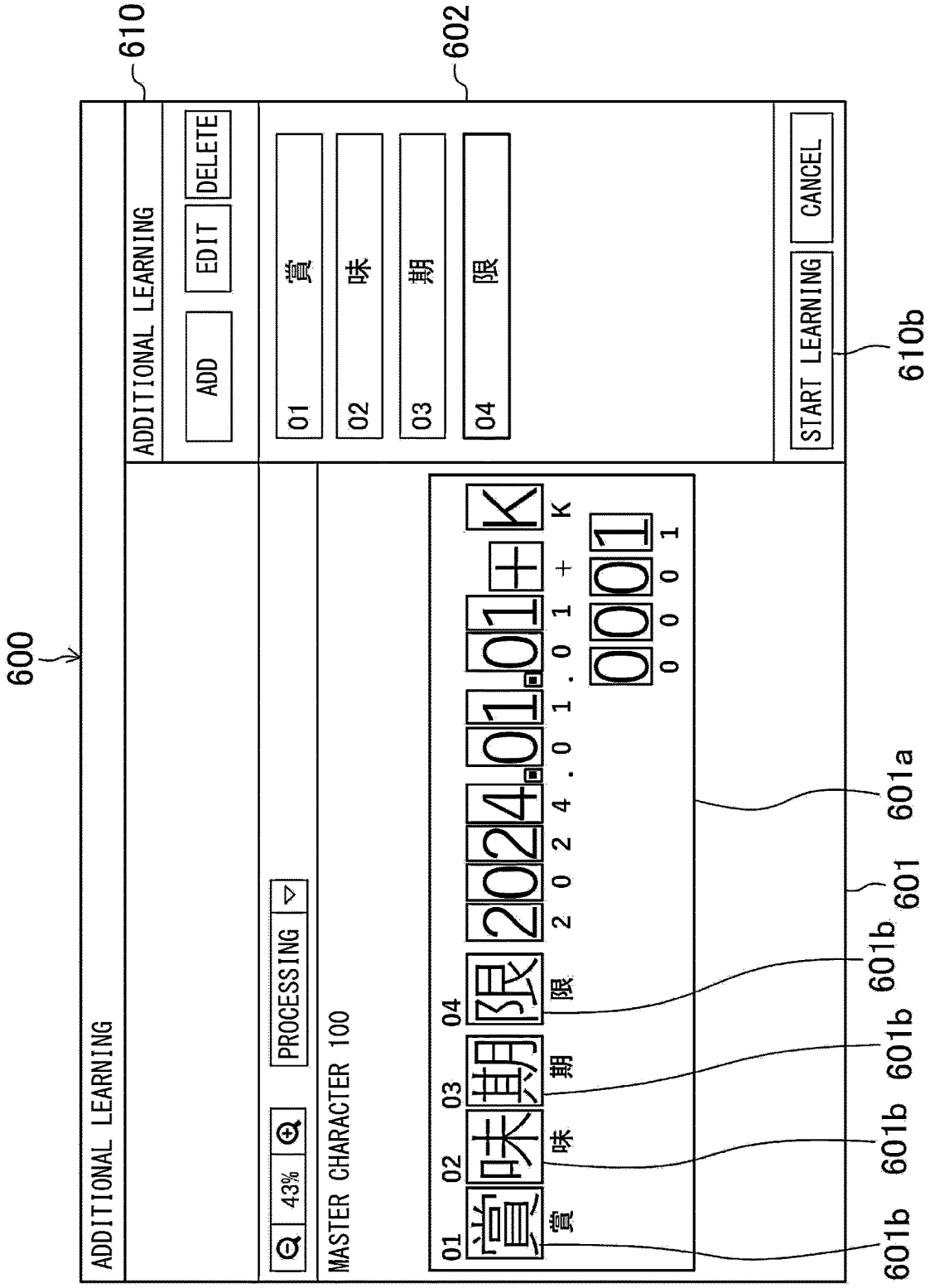

600
610
602
ADDITIONAL LEARNING
ADD
EDIT
DELETE
01 賞
02 味
03 期
04 限
START LEARNING
CANCEL
610b
43%
PROCESSING
MASTER CHARACTER 100
01 賞
02 味
03 期
04 限
2024.01.01+K
0001
601a
601
601b

FIG. 32

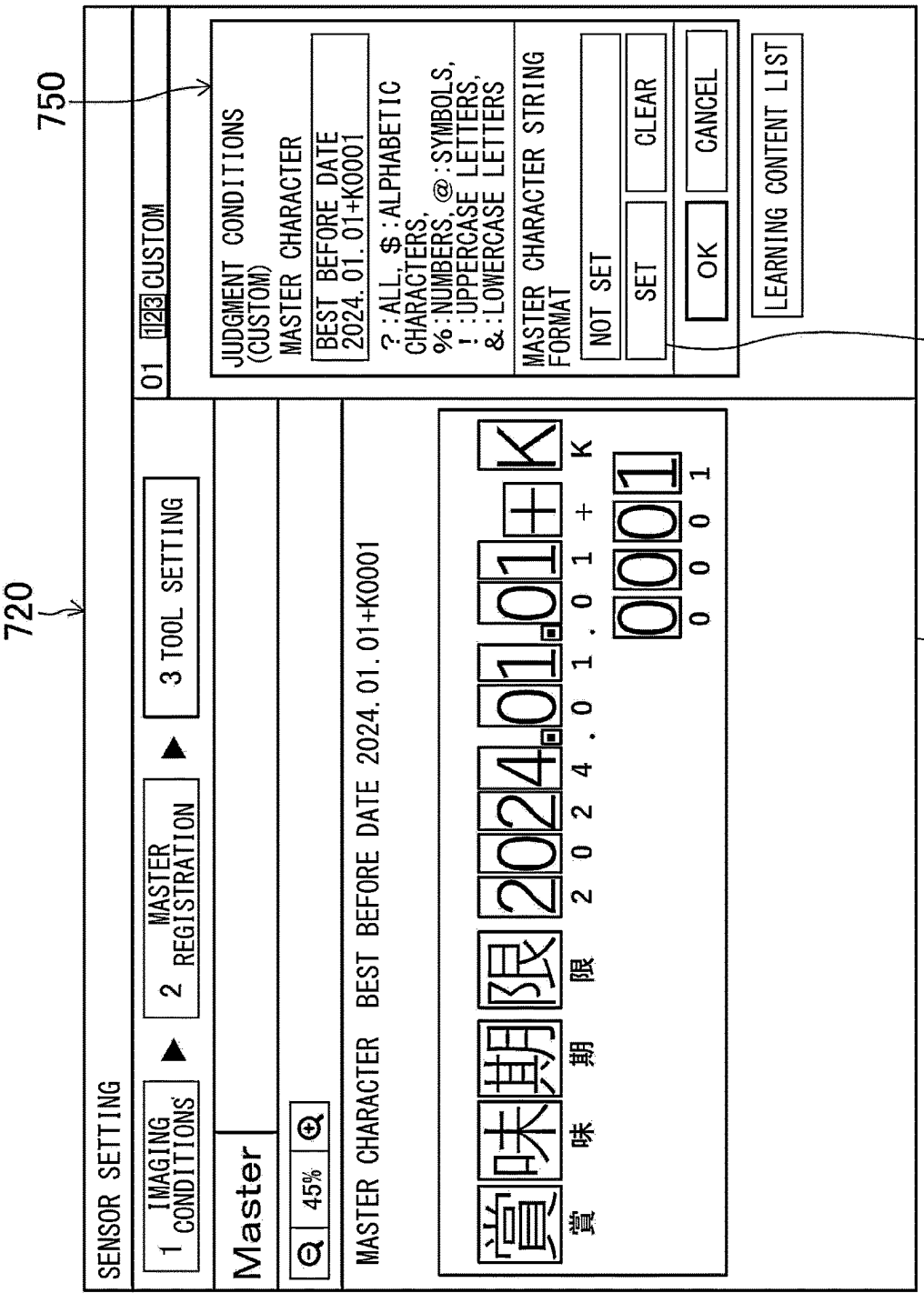

720
750
751
721
SENSOR SETTING
1 IMAGING CONDITIONS
2 MASTER REGISTRATION
3 TOOL SETTING
01 CUSTOM
Master
45%
MASTER CHARACTER BEST BEFORE DATE 2024.01.01+K0001
賞味期限 2024.01.01+K
賞 味 期 限 2 0 2 4 . 0 1 . 0 1 + K
0 0 0 1
JUDGMENT CONDITIONS (CUSTOM)
MASTER CHARACTER
BEST BEFORE DATE 2024.01.01+K0001
?:ALL, $:ALPHABETIC CHARACTERS, %:NUMBERS, @:SYMBOLS, !:UPPERCASE LETTERS, &:LOWERCASE LETTERS
MASTER CHARACTER STRING FORMAT
NOT SET
SET
CLEAR
OK
CANCEL
LEARNING CONTENT LIST

FIG. 33

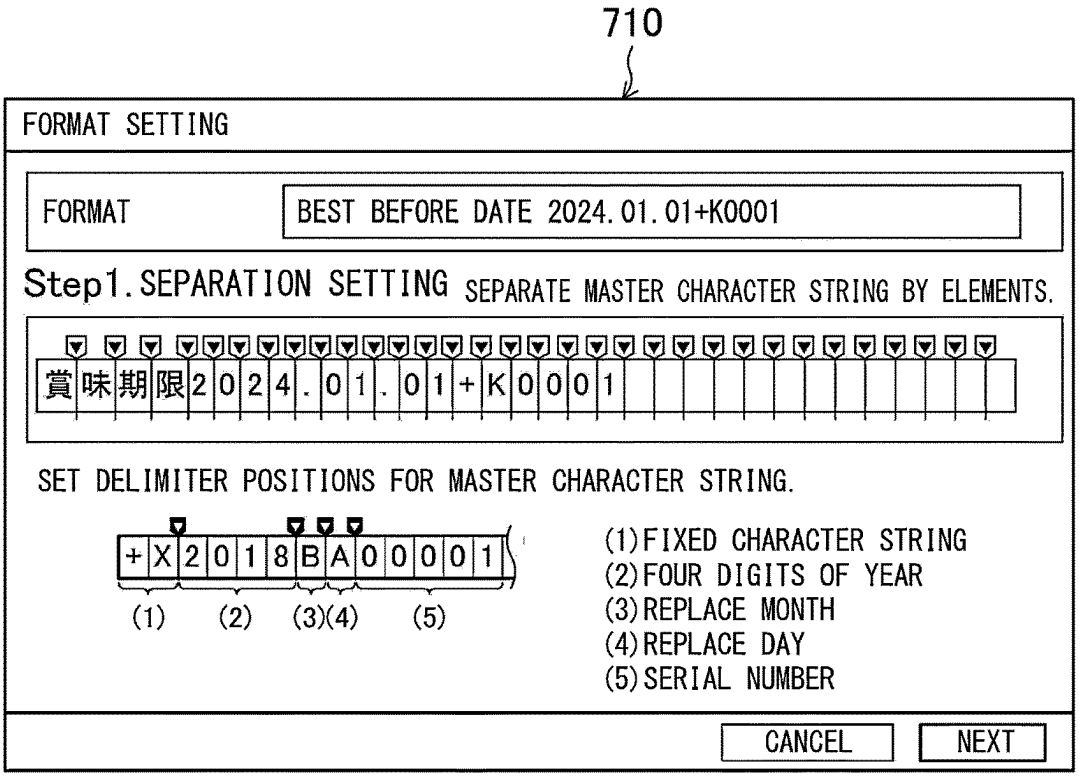

710
FORMAT SETTING
FORMAT
BEST BEFORE DATE 2024.01.01+K0001
Step1.SEPARATION SETTING SEPARATE MASTER CHARACTER STRING BY ELEMENTS.
賞味期限2024.01.01+K0001
SET DELIMITER POSITIONS FOR MASTER CHARACTER STRING.
+X2018BA00001
(1) (2) (3)(4) (5)
(1)FIXED CHARACTER STRING
(2)FOUR DIGITS OF YEAR
(3)REPLACE MONTH
(4)REPLACE DAY
(5)SERIAL NUMBER
CANCEL
NEXT

FIG. 34

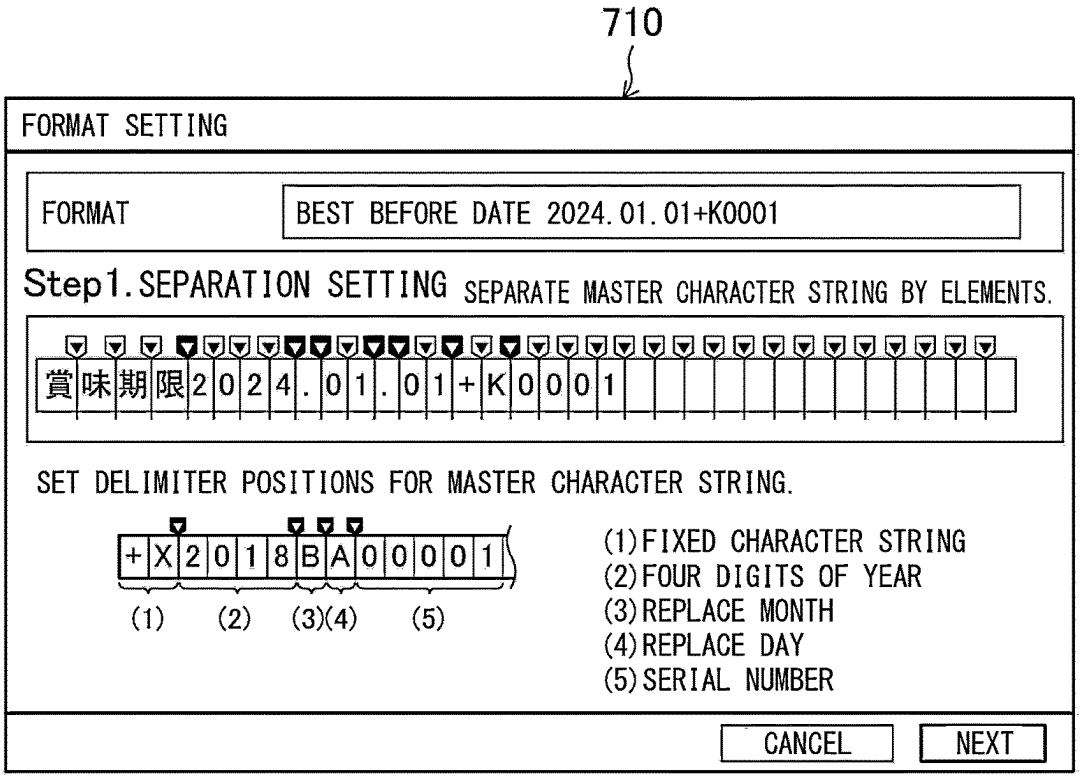

710
FORMAT SETTING
FORMAT
BEST BEFORE DATE 2024.01.01+K0001
Step1.SEPARATION SETTING SEPARATE MASTER CHARACTER STRING BY ELEMENTS.
賞味期限2024.01.01+K0001
SET DELIMITER POSITIONS FOR MASTER CHARACTER STRING.
+X2018BA00001
(1) (2) (3)(4) (5)
(1)FIXED CHARACTER STRING
(2)FOUR DIGITS OF YEAR
(3)REPLACE MONTH
(4)REPLACE DAY
(5)SERIAL NUMBER
CANCEL
NEXT

FIG. 35

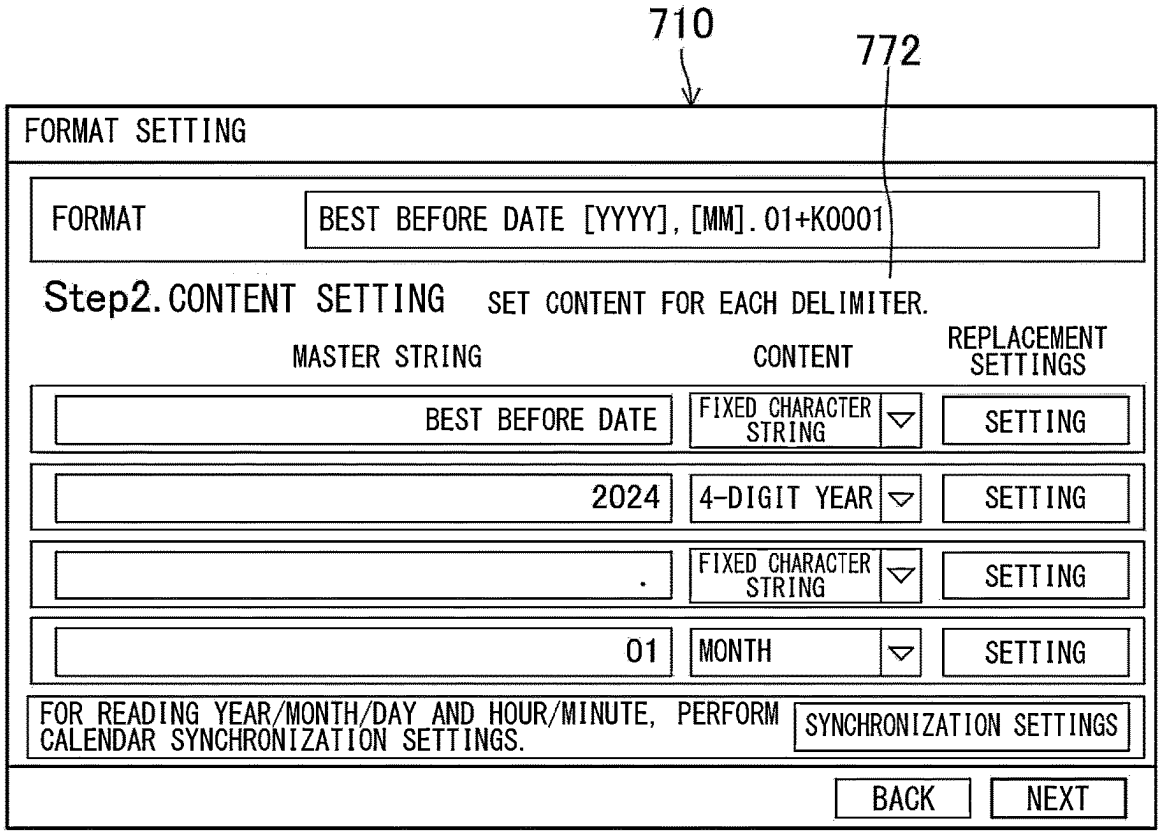

710
772
FORMAT SETTING
FORMAT
BEST BEFORE DATE [YYYY].[MM].01+K0001
Step2. CONTENT SETTING
SET CONTENT FOR EACH DELIMITER.
MASTER STRING
CONTENT
REPLACEMENT SETTINGS
BEST BEFORE DATE
FIXED CHARACTER STRING
SETTING
2024
4-DIGIT YEAR
SETTING
.
FIXED CHARACTER STRING
SETTING
01
MONTH
SETTING
FOR READING YEAR/MONTH/DAY AND HOUR/MINUTE, PERFORM CALENDAR SYNCHRONIZATION SETTINGS.
SYNCHRONIZATION SETTINGS
BACK
NEXT

FIG. 36

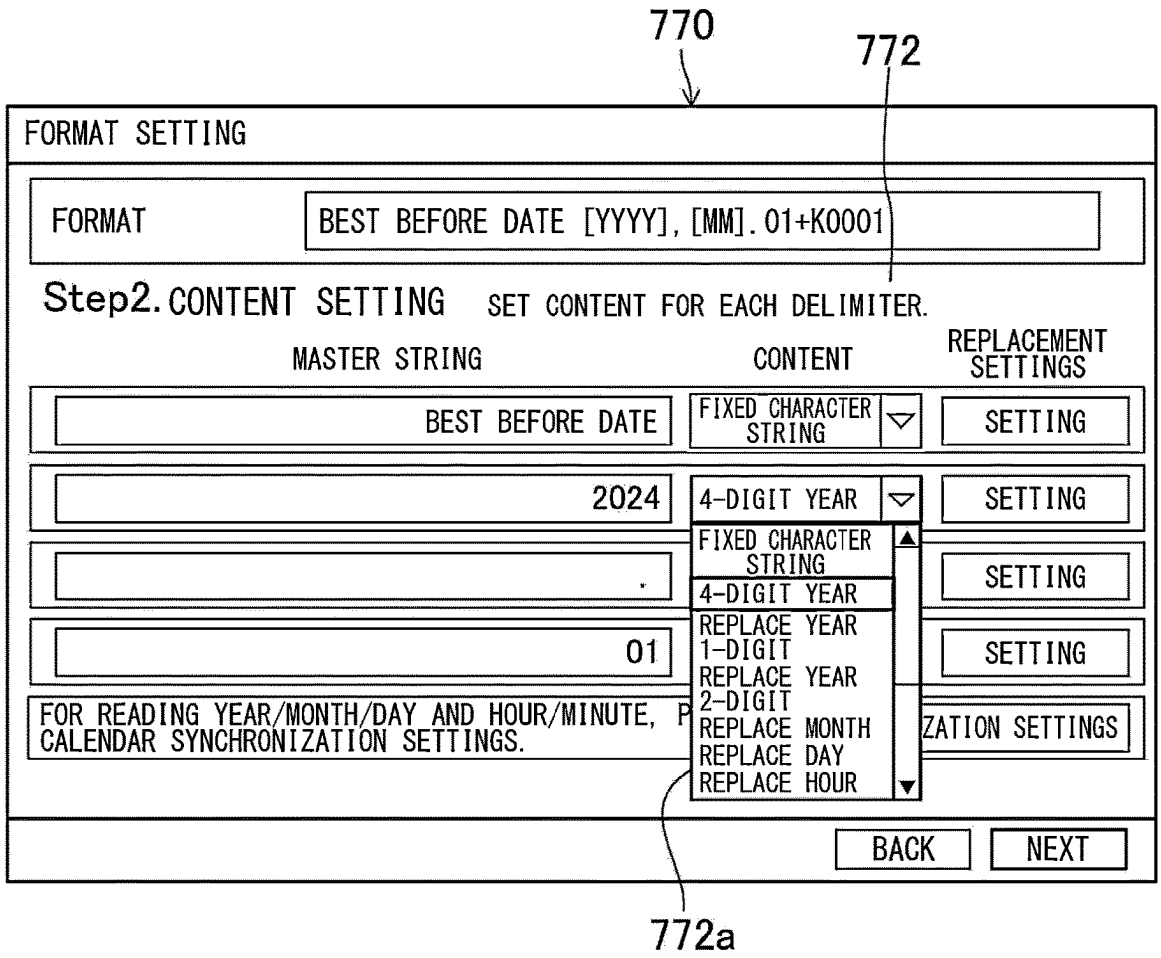

770
772
FORMAT SETTING
FORMAT
BEST BEFORE DATE [YYYY],[MM].01+K0001
Step2. CONTENT SETTING
SET CONTENT FOR EACH DELIMITER.
MASTER STRING
CONTENT
REPLACEMENT SETTINGS
BEST BEFORE DATE
FIXED CHARACTER STRING
SETTING
2024
4-DIGIT YEAR
SETTING
FIXED CHARACTER STRING
4-DIGIT YEAR
REPLACE YEAR 1-DIGIT
REPLACE YEAR 2-DIGIT
REPLACE MONTH
REPLACE DAY
REPLACE HOUR
SETTING
01
SETTING
FOR READING YEAR/MONTH/DAY AND HOUR/MINUTE, P
CALENDAR SYNCHRONIZATION SETTINGS.
ZATION SETTINGS
BACK
NEXT
772a

FIG. 37

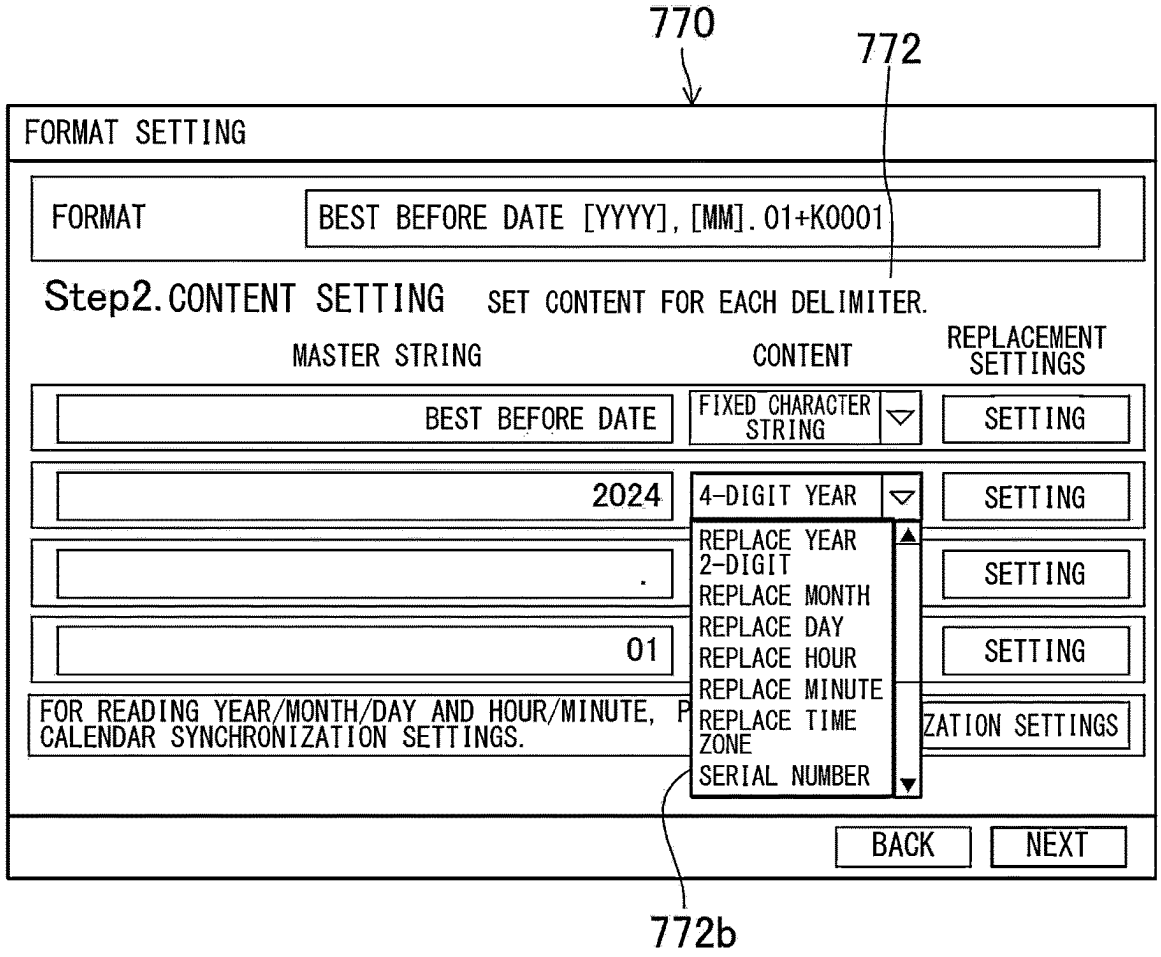

770
772
FORMAT SETTING
FORMAT
BEST BEFORE DATE [YYYY],[MM].01+K0001
Step2.CONTENT SETTING
SET CONTENT FOR EACH DELIMITER.
MASTER STRING
CONTENT
REPLACEMENT SETTINGS
BEST BEFORE DATE
FIXED CHARACTER STRING
SETTING
2024
4-DIGIT YEAR
SETTING
.
SETTING
01
SETTING
FOR READING YEAR/MONTH/DAY AND HOUR/MINUTE, P
CALENDAR SYNCHRONIZATION SETTINGS.
ZATION SETTINGS
REPLACE YEAR 2-DIGIT
REPLACE MONTH
REPLACE DAY
REPLACE HOUR
REPLACE MINUTE
REPLACE TIME ZONE
SERIAL NUMBER
BACK
NEXT
772b

FIG. 38

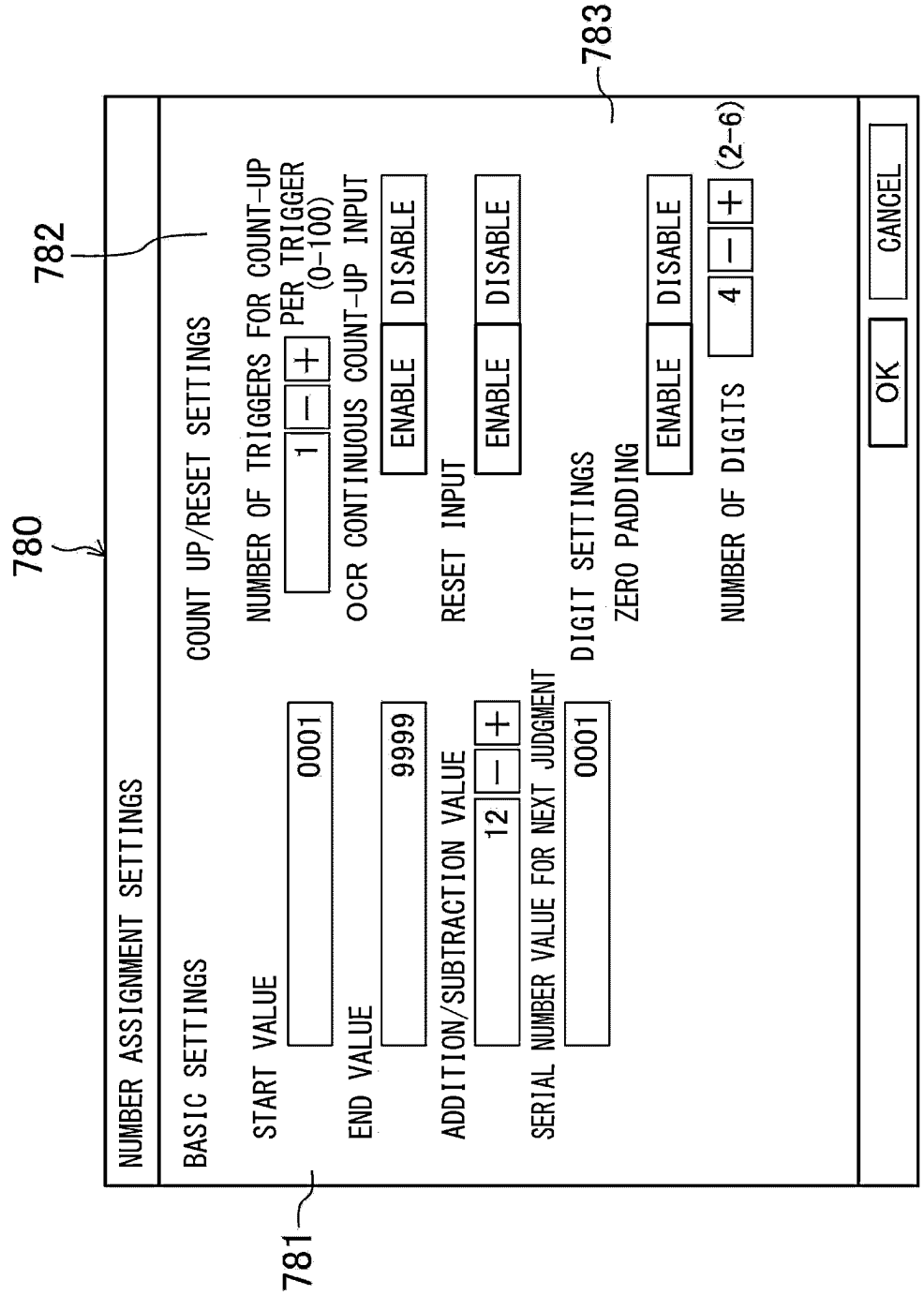

780
781
782
783
NUMBER ASSIGNMENT SETTINGS
BASIC SETTINGS
START VALUE
0001
END VALUE
9999
ADDITION/SUBTRACTION VALUE
12
SERIAL NUMBER VALUE FOR NEXT JUDGMENT
0001
COUNT UP/RESET SETTINGS
NUMBER OF TRIGGERS FOR COUNT-UP
1
PER TRIGGER
(0-100)
OCR CONTINUOUS COUNT-UP INPUT
ENABLE
DISABLE
RESET INPUT
ENABLE
DISABLE
DIGIT SETTINGS
ZERO PADDING
ENABLE
DISABLE
NUMBER OF DIGITS
4
(2-6)
OK
CANCEL

FIG. 39

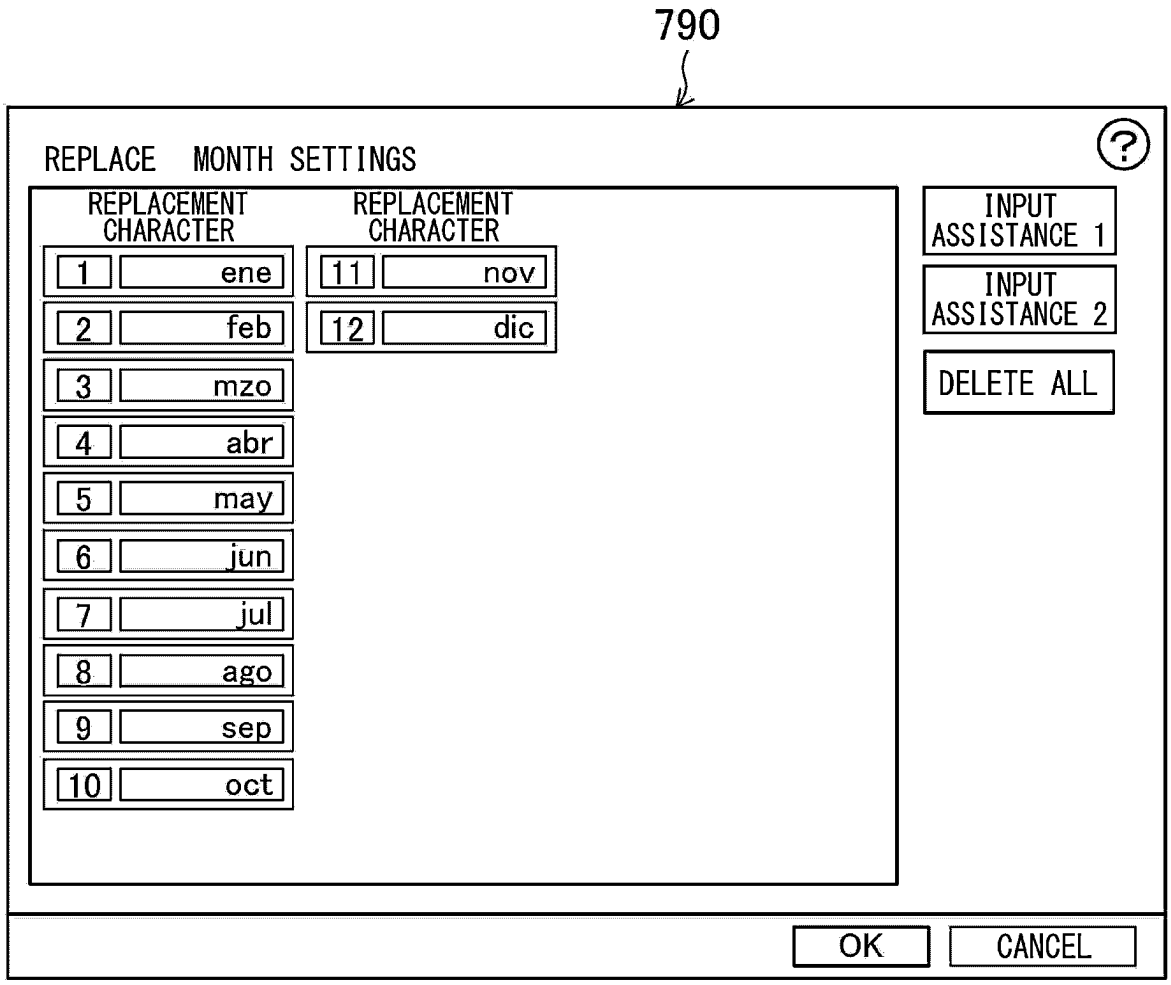

790
REPLACE MONTH SETTINGS
REPLACEMENT CHARACTER
REPLACEMENT CHARACTER
1 ene
2 feb
3 mzo
4 abr
5 may
6 jun
7 jul
8 ago
9 sep
10 oct
11 nov
12 dic
INPUT ASSISTANCE 1
INPUT ASSISTANCE 2
DELETE ALL
OK
CANCEL

FIG. 40

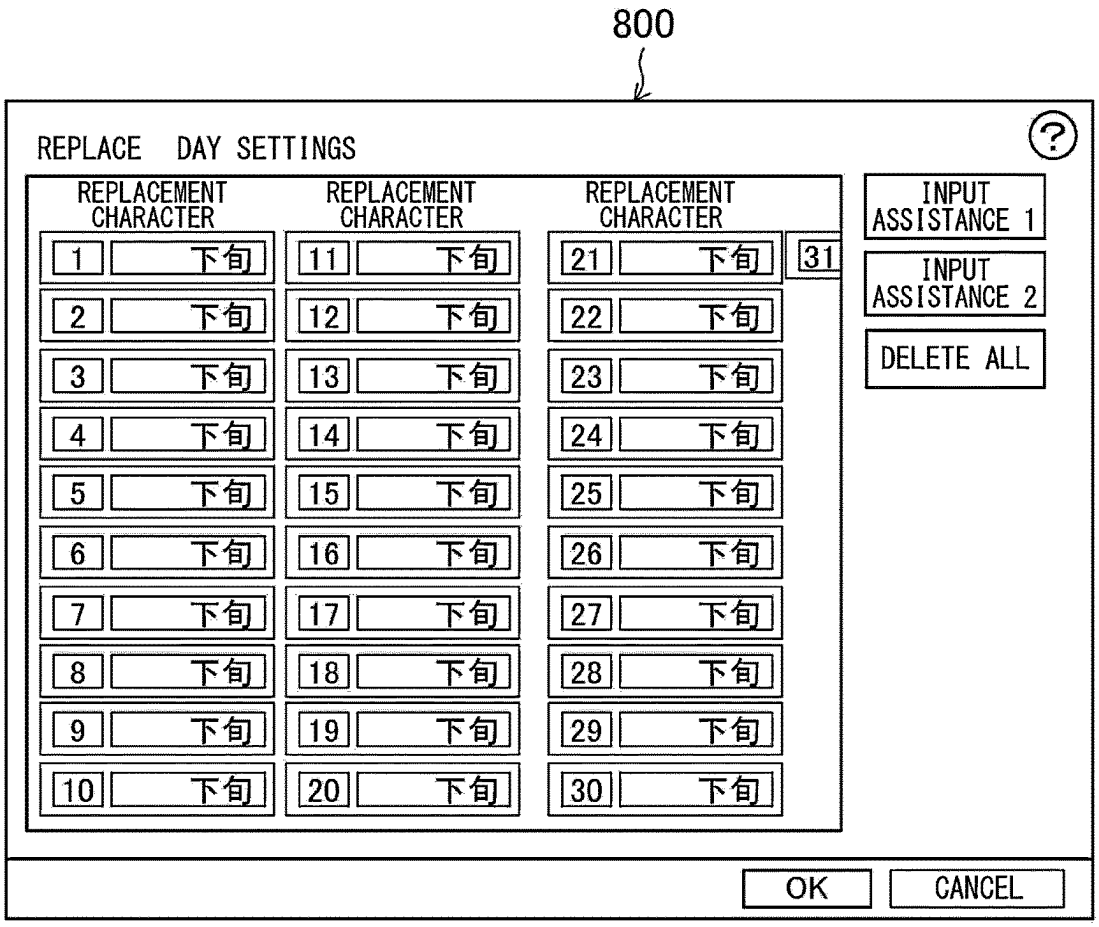

800
REPLACE DAY SETTINGS
REPLACEMENT CHARACTER
REPLACEMENT CHARACTER
REPLACEMENT CHARACTER
1 下旬
2 下旬
3 下旬
4 下旬
5 下旬
6 下旬
7 下旬
8 下旬
9 下旬
10 下旬
11 下旬
12 下旬
13 下旬
14 下旬
15 下旬
16 下旬
17 下旬
18 下旬
19 下旬
20 下旬
21 下旬
22 下旬
23 下旬
24 下旬
25 下旬
26 下旬
27 下旬
28 下旬
29 下旬
30 下旬
31
INPUT ASSISTANCE 1
INPUT ASSISTANCE 2
DELETE ALL
OK
CANCEL

FIG. 41

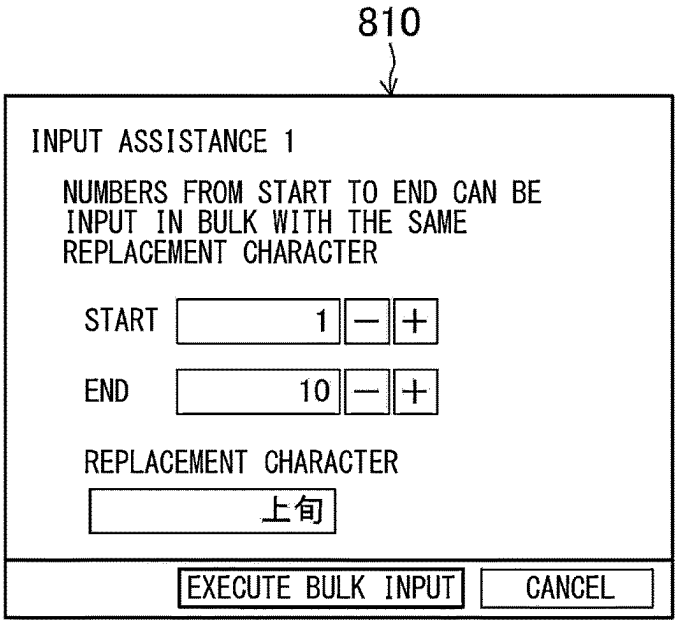

810
INPUT ASSISTANCE 1
NUMBERS FROM START TO END CAN BE INPUT IN BULK WITH THE SAME REPLACEMENT CHARACTER
START 1 − +
END 10 − +
REPLACEMENT CHARACTER
上旬
EXECUTE BULK INPUT
CANCEL

FIG. 42

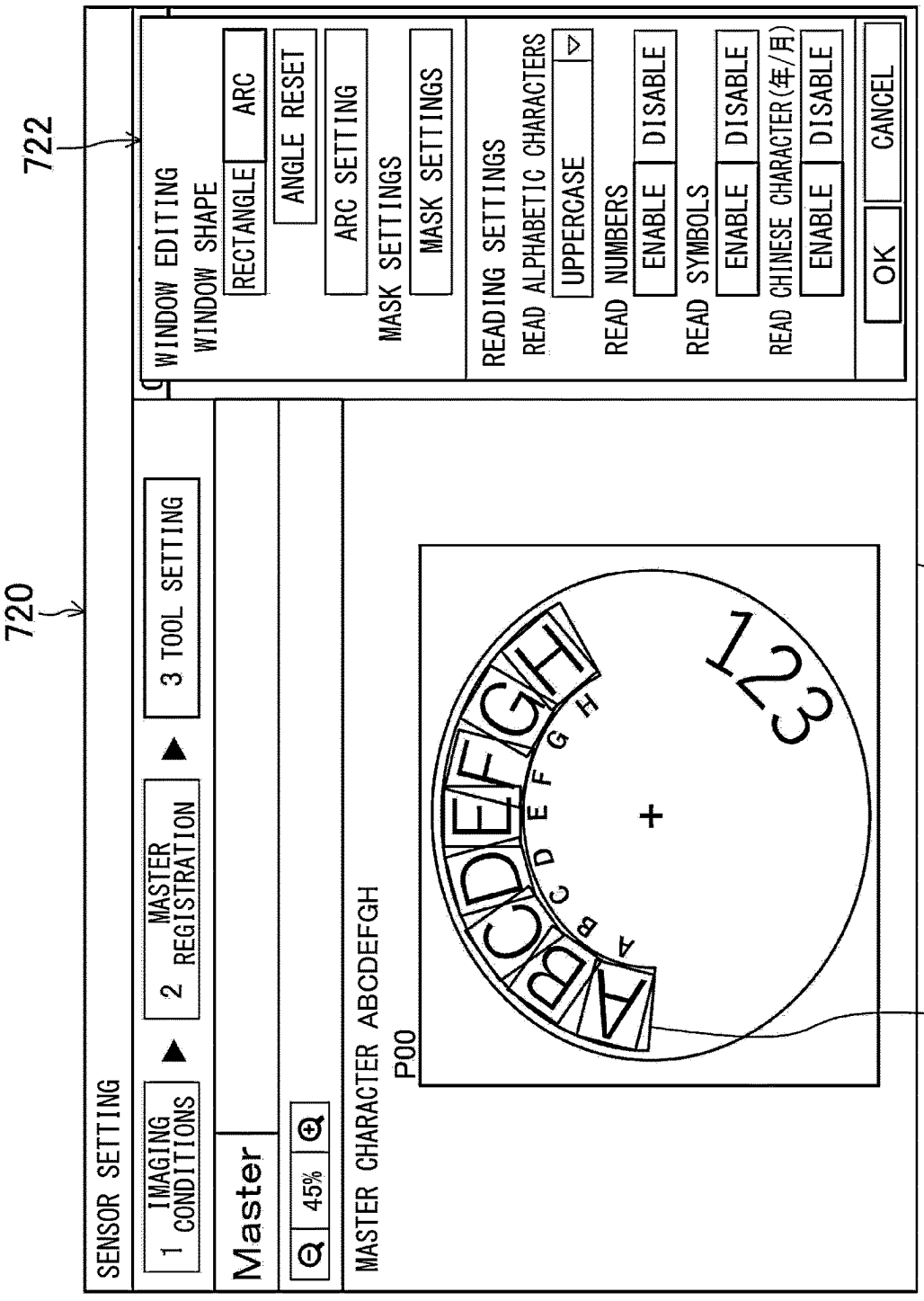

720
722
721
721a
SENSOR SETTING
1 IMAGING CONDITIONS
2 MASTER REGISTRATION
3 TOOL SETTING
Master
45%
MASTER CHARACTER ABCDEFGH
P00
WINDOW EDITING
WINDOW SHAPE
RECTANGLE
ARC
ANGLE RESET
ARC SETTING
MASK SETTINGS
MASK SETTINGS
READING SETTINGS
READ ALPHABETIC CHARACTERS
UPPERCASE
READ NUMBERS
ENABLE
DISABLE
READ SYMBOLS
ENABLE
DISABLE
READ CHINESE CHARACTER(年/月)
ENABLE
DISABLE
OK
CANCEL

FIG. 43

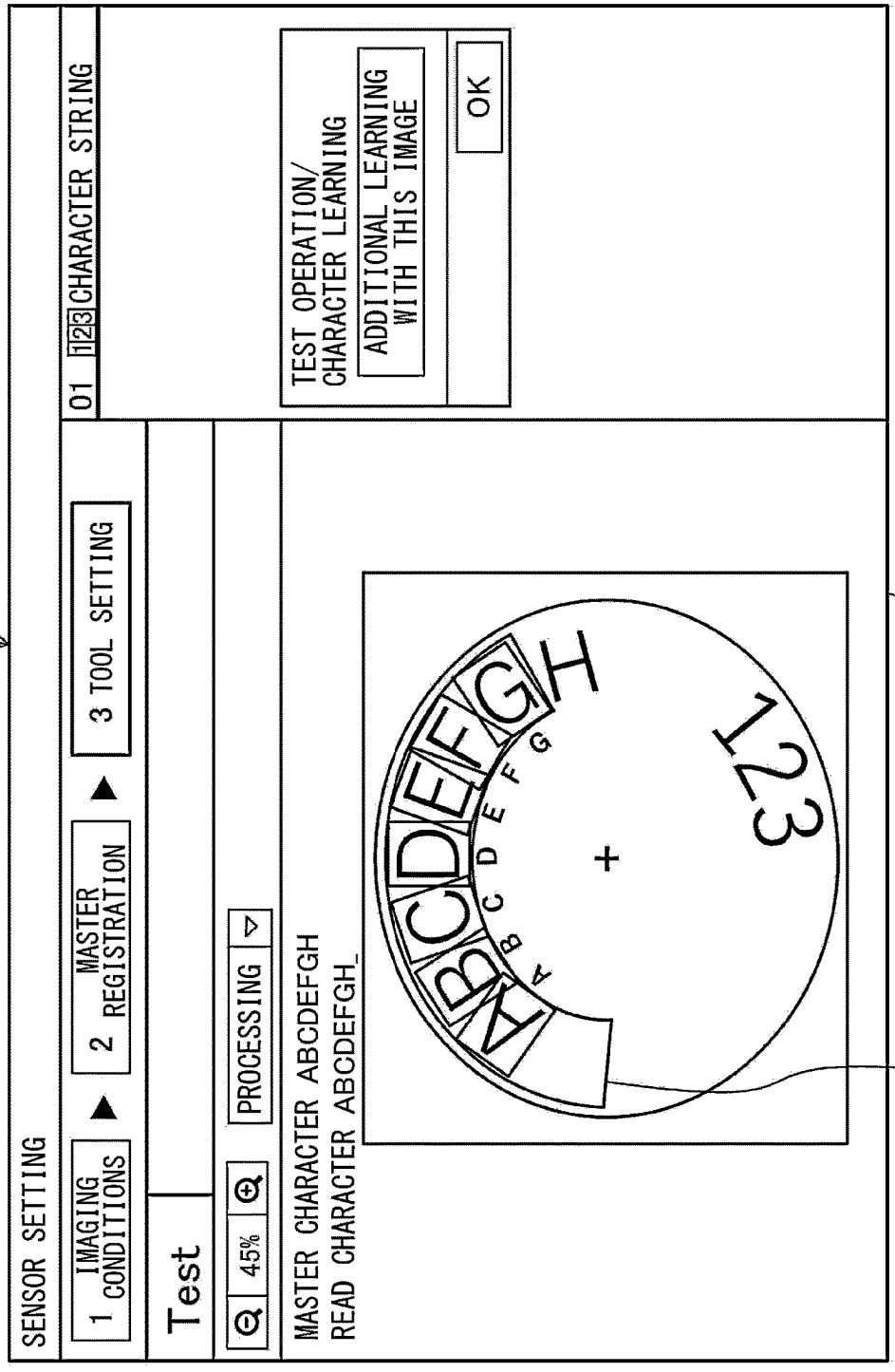

720
SENSOR SETTING
1 IMAGING CONDITIONS
2 MASTER REGISTRATION
3 TOOL SETTING
01 123 CHARACTER STRING
Test
45%
PROCESSING
MASTER CHARACTER ABCDEFGH
READ CHARACTER ABCDEFGH_
TEST OPERATION/ CHARACTER LEARNING
ADDITIONAL LEARNING WITH THIS IMAGE
OK
721
721a

FIG. 44

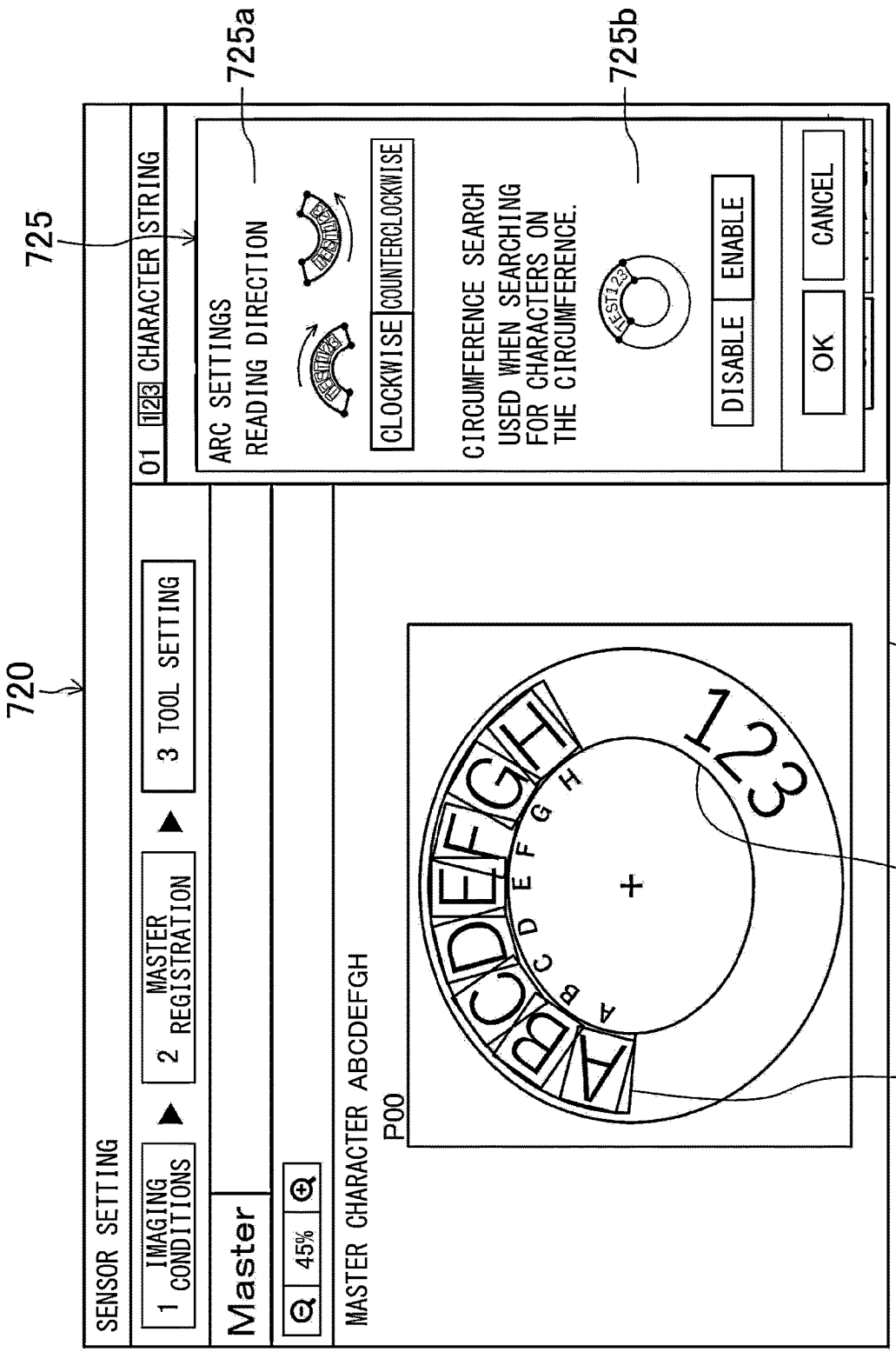

720
725
725a
725b
721
721a
721b
SENSOR SETTING
1 IMAGING CONDITIONS
2 MASTER REGISTRATION
3 TOOL SETTING
Master
45%
MASTER CHARACTER ABCDEFGH
P00
01 CHARACTER STRING
ARC SETTINGS
READING DIRECTION
CLOCKWISE
COUNTERCLOCKWISE
CIRCUMFERENCE SEARCH
USED WHEN SEARCHING
FOR CHARACTERS ON
THE CIRCUMFERENCE.
DISABLE
ENABLE
OK
CANCEL

FIG. 45

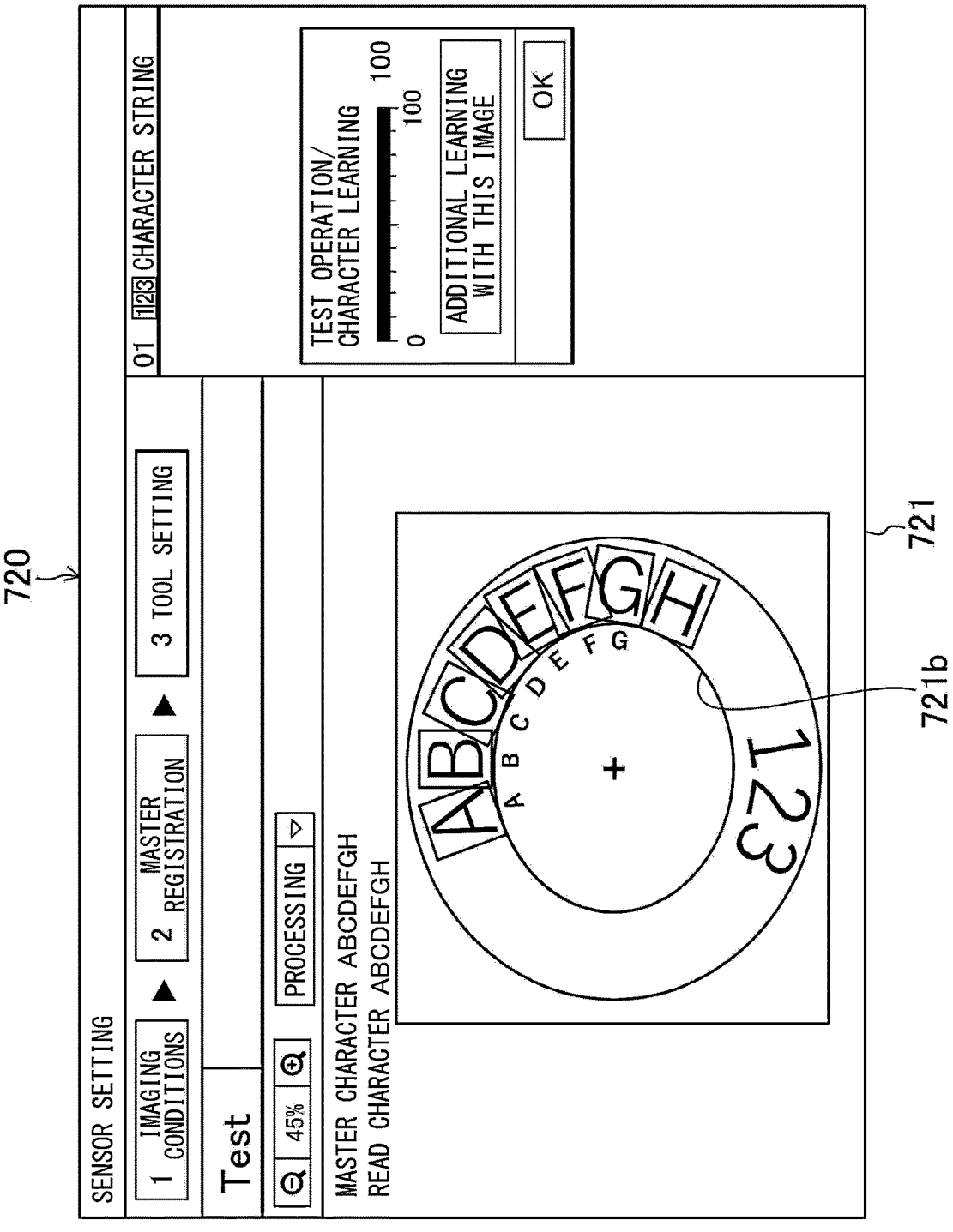

720
SENSOR SETTING
1 IMAGING CONDITIONS
2 MASTER REGISTRATION
3 TOOL SETTING
01 123 CHARACTER STRING
Test
45%
PROCESSING
MASTER CHARACTER ABCDEFGH
READ CHARACTER ABCDEFGH
TEST OPERATION/
CHARACTER LEARNING
0
100
100
ADDITIONAL LEARNING WITH THIS IMAGE
OK
721
721b

FIG. 46

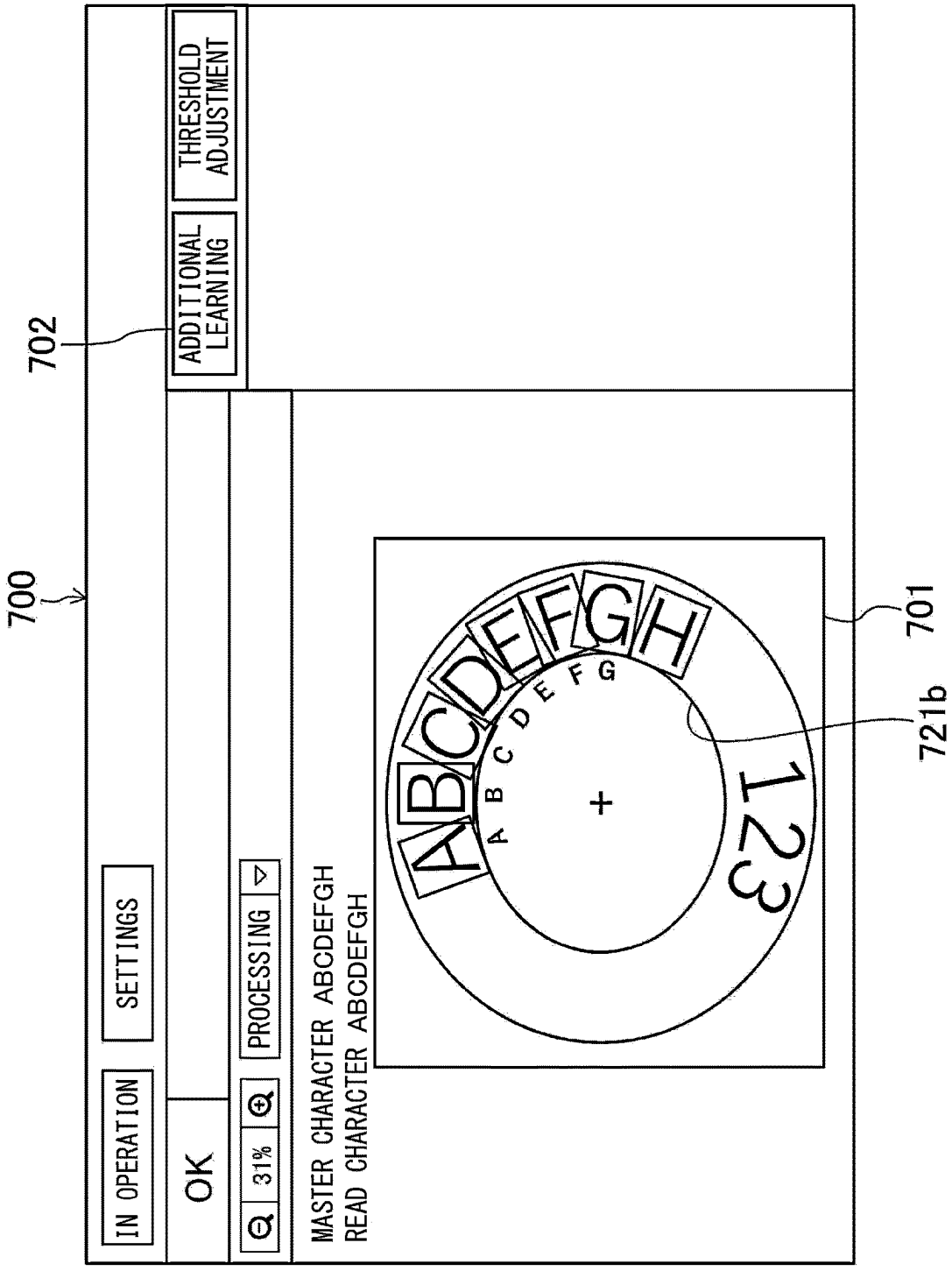

700
IN OPERATION
SETTINGS
OK
Q
31%
PROCESSING
MASTER CHARACTER ABCDEFGH
READ CHARACTER ABCDEFGH
702
ADDITIONAL LEARNING
THRESHOLD ADJUSTMENT
701
721b

FIG. 47

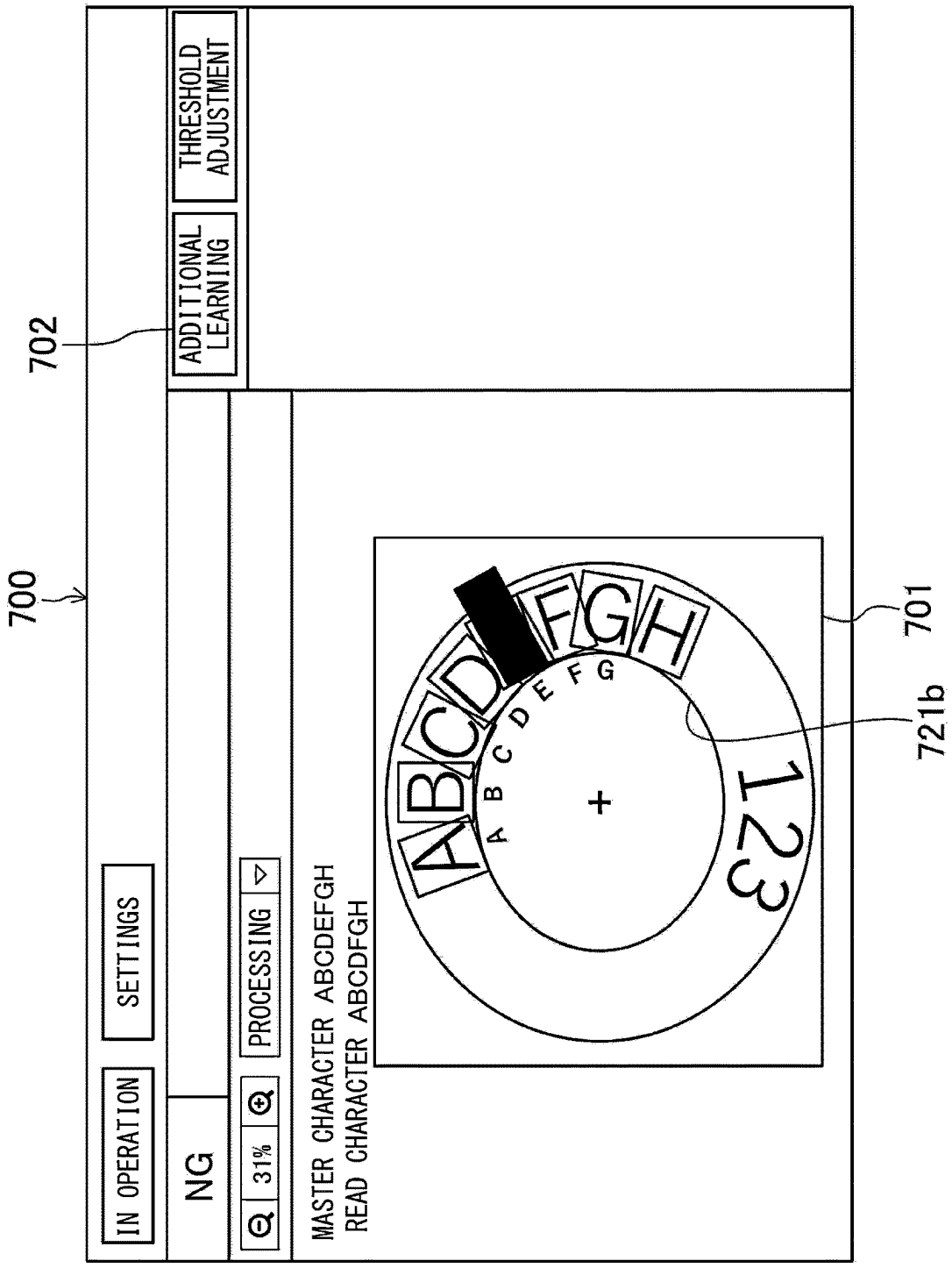

700
702
701
721b
IN OPERATION
SETTINGS
ADDITIONAL LEARNING
THRESHOLD ADJUSTMENT
NG
31%
PROCESSING
MASTER CHARACTER ABCDEFGH
READ CHARACTER ABCDFGH
ABCDFGH
123

FIG. 48

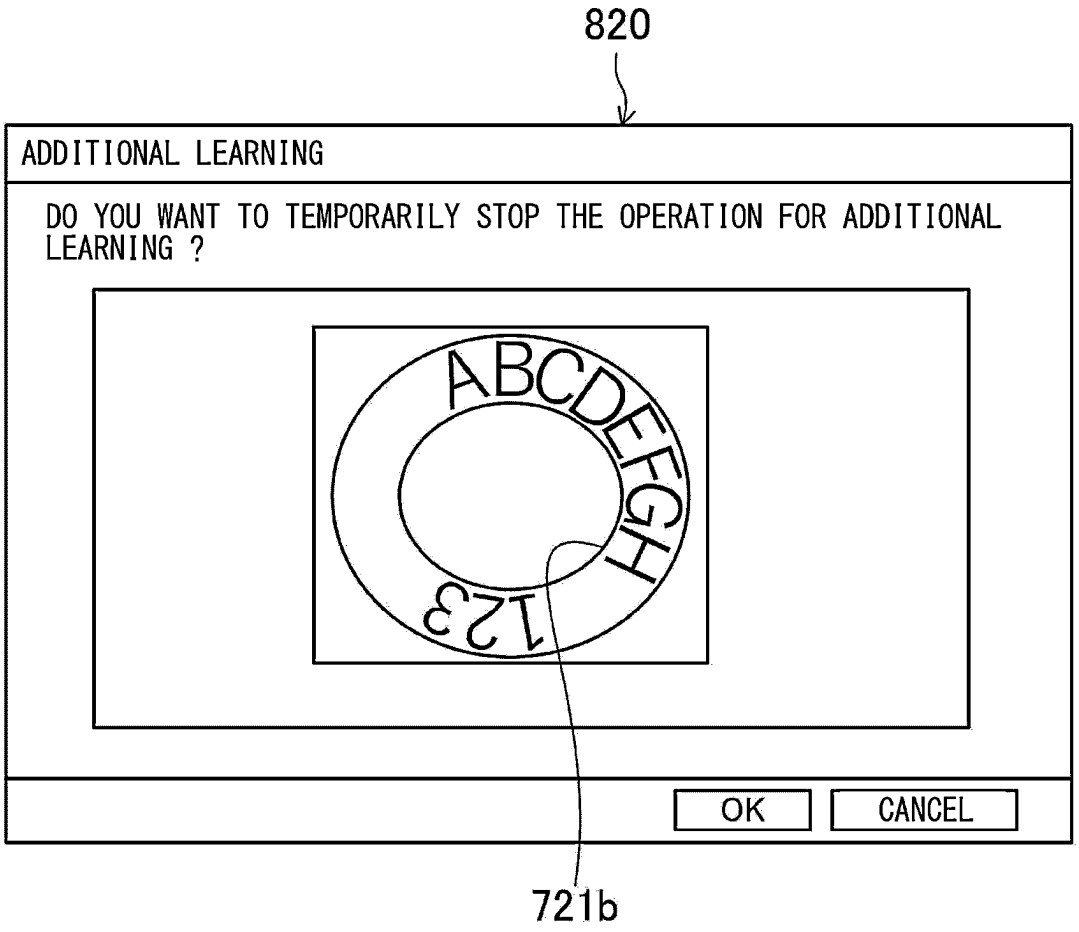

820
ADDITIONAL LEARNING
DO YOU WANT TO TEMPORARILY STOP THE OPERATION FOR ADDITIONAL LEARNING ?
ABCDEFGH
123
OK
CANCEL
721b

FIG. 49

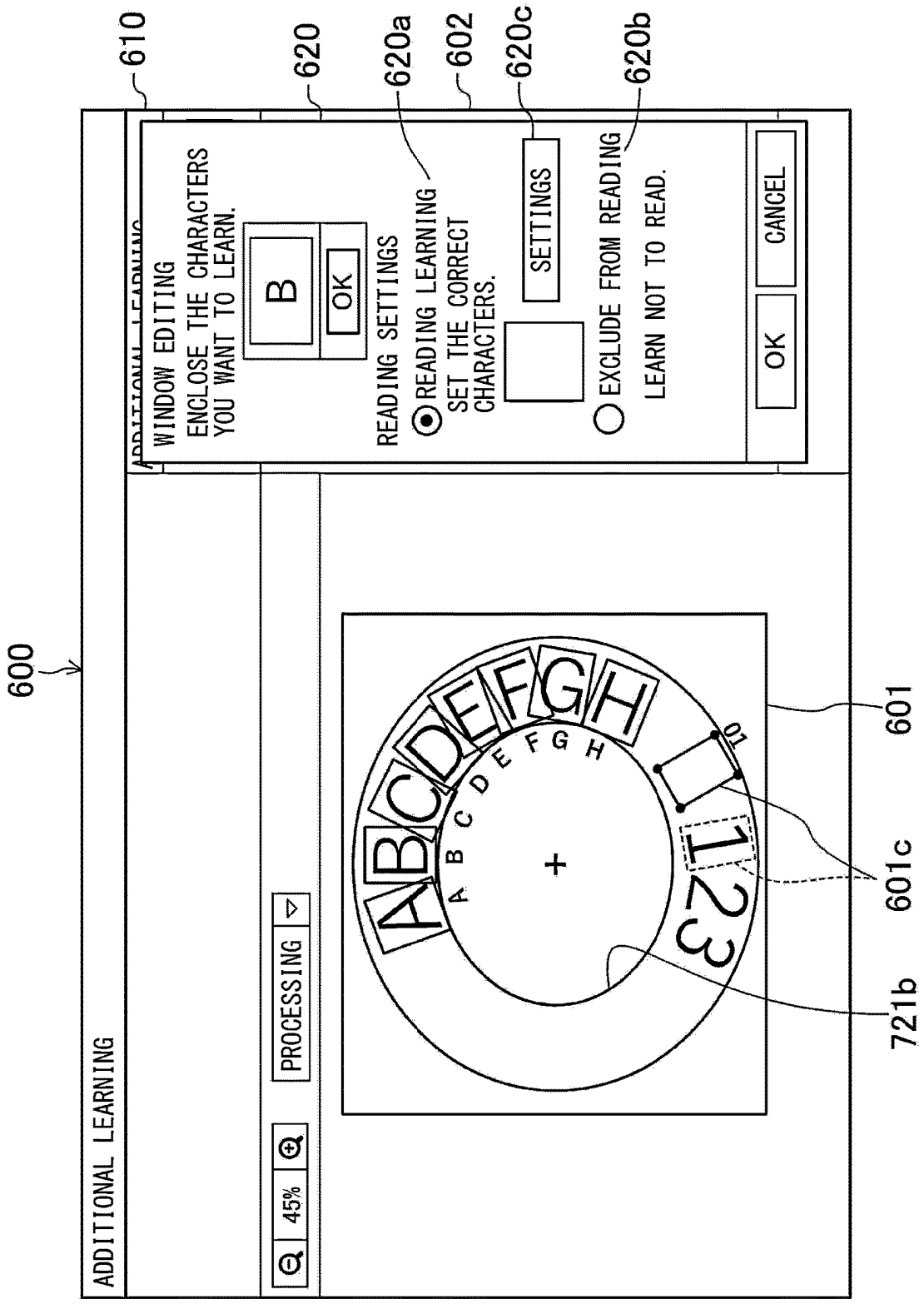

600
610
620
620a
602
620c
620b
ADDITIONAL LEARNING
WINDOW EDITING
ENCLOSE THE CHARACTERS YOU WANT TO LEARN.
B
OK
READING SETTINGS
READING LEARNING
SET THE CORRECT CHARACTERS.
SETTINGS
EXCLUDE FROM READING
LEARN NOT TO READ.
OK
CANCEL
45%
PROCESSING
601
601c
721b

IMAGE INSPECTION DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims foreign priority based on Japanese Patent Application No. 2024-017579, filed Feb. 8, 2024, and No. 2024-042628, filed Mar. 18, 2024, the contents of which are incorporated herein by references.

BACKGROUND OF THE INVENTION

1. Technical Field

[0002] The present disclosure relates to an image inspection device implemented with a trained network that performs classification tasks for character recognition.

2. Description of the Related Art

[0003] For example, in the FA industry, image inspection devices that replace the process of human visual inspection of workpieces are widely known. The image inspection device captures workpiece images and judges the captured images based on certain criteria. When the image inspection device is an image sensor, the judgment result is output to external devices such as a programmable logic controller (PLC) via I/O output.

[0004] When the criteria used for the judgment of the image inspection device are based on certain image features, even changes in image features that do not affect the results of visual inspections by humans may potentially influence the judgment results of the image inspection device.

[0005] Therefore, in order to obtain judgment results closer to those of visual inspections, an image inspection device utilizing an image recognition model obtained through machine learning is known, for example, as disclosed in JP 2020-187072 A. In the image inspection device of JP 2020-187072 A, a learning device is generated that identifies good product images and defective product images by learning good product images with attributes assigned as good products and defective product images with attributes assigned as defective products, and it is configured to input newly acquired images into the learning device during operation to perform quality judgment.

SUMMARY OF THE INVENTION

[0006] By the way, there is a device equipped with character recognition (OCR) that recognizes the character image, which is the character portion of the captured image of the work with characters assigned, identifies the characters on the work, and determines whether the corresponding characters conform to the judgment criteria using an image recognition model.

[0007] As a recognition method using OCR, there is a method called the sliding window method, for example. In the sliding window method, first, the size for extracting characters from the image is determined. For example, on an image captured of an actual workpiece with characters, a frame is set to enclose the characters on the workpiece. The size of this frame becomes the character extraction size. After the character extraction size is determined, when the OCR target image is input during operation, the OCR target image is extracted into multiple image areas based on the predetermined character extraction size. Each of the extracted multiple image areas undergoes verification to determine whether it has similar features to any character, and for example, if a certain area is determined to have the features of "A" (or has features similar to "A" to the extent that it can be judged as class "A" compared to other classes), that area is recognized as an image of the character "A." At this time, the verification target of the features is slightly shifted for verification, so conceptually, the verification target frame (window) slides, hence it is called the sliding window method.

[0008] However, in the sliding window method, in order to determine which character corresponds to the features of the area of the extracted size, there are cases where character images with different sizes depending on the character type (for example, the "I" in proportional font or a period) are extracted as character images that include adjacent characters, which may lower the recognition accuracy.

[0009] In OCR, there may be cases where it is desired to increase the types of character sizes that can be recognized by the image recognition model. However, in the case of the sliding window method, it is necessary to scan and classify features while changing the size of the window, which results in an enormous amount of computational processing.

[0010] The present disclosure is made in consideration of such points, and its purpose is to enable handling while reducing processing load even if the recognizable character size is increased.

[0011] According to one embodiment, an image inspection device execute a pre-trained character recognition model to classify an image area, which is a partial area in an input image data, into a first character type class.

[0012] The image inspection device includes a control unit that executes the pre-trained character recognition model and functions as a learning data generation unit that generates learning data and a learning execution unit that executes updating of the pre-trained character recognition model based on the learning data. The pre-trained character recognition model includes a feature extraction unit that extracts a feature from the input image data, the feature indicating a characteristic of an image data, and a character type output unit that outputs a character type based on the feature extracted by the feature extraction unit. The learning data generation unit generates the learning data that includes learning image data, specified position information indicating a relative position of a character in an image of the learning image data, specified character type information indicating the character type of the character located at the relative position, and specified size information indicating a size of the character in the image.

[0013] The learning execution unit updates the pre-trained character recognition model so as to classify the feature, the feature being extracted in a case that the learning image data is input to the feature extraction unit and corresponding to the relative position indicated by the specified position information, into a specified character type class corresponding to a combination of the character type indicated by the specified character type information and the size indicated by the specified size information.

[0014] According to this configuration, the learning data generated by the learning data generation unit includes not only the specified character type information indicating the character type but also the specified position information indicating the relative position of the characters in the learning image data and the specified size information

indicating the size of the characters in the image. As a result, the learning execution unit learns the combination of the specified character size and the specified character type in the learning data as a new character type class, thereby reducing the learning load related to the character size while increasing the recognizable character sizes.

[0015] The control unit may be configured to have a convolutional operation network inference accelerator that performs operations of a convolutional neural network as the feature extraction unit.

[0016] The feature extraction unit may include a character type class feature extraction unit that extracts features related to the character type class of the image area, and a foreground-background feature extraction unit that extracts foreground features, which are features indicating whether the image area is foreground or background. In addition, it has a foreground output unit that determines whether the image area is foreground based on the foreground features, and the character type output unit can output a value indicating the character type of the image area based on the character type features corresponding to the image area determined to be foreground.

[0017] That is, for example, if a classifier that includes the background is used, any "character" class close to the "background" class will exist in the feature space handled by the classifier, and labeling such "characters" will cause all nearby "background" vectors to be classified into the corresponding "character" class. However, by narrowing down whether the image area is foreground or background and training as in this embodiment, such problems are less likely to occur, and the determination accuracy is improved.

[0018] The feature extraction unit may include a character type class feature extraction unit that extracts features related to the character type class of the image area, and a size feature extraction unit that extracts size features related to the size of the image area. In this case, the character type output unit can output the size of the character image in the image area based on the specified size included in the specified character type class when the character type class feature corresponds to the specified character type class that is a combination of the character type and the specified size.

[0019] The size output unit that outputs the size of the character image in the image area based on the size feature may be provided. In this case, the size output unit can output the size of the character image when the character type class feature does not belong to the specified character type class corresponding to the combination of the character type and the specified size.

[0020] As explained above, since the learning data includes specified character type information, specified position information indicating the relative position of characters in the image, and specified size information indicating the size of the characters, it is possible to learn the combination of character size and character type as a new character type class, thereby increasing the recognizable character sizes while reducing the learning load related to character size.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] FIG. **1** is a diagram explaining the operation of the image inspection device according to an embodiment of the present invention.

[0022] FIG. **2** is a hardware configuration diagram of the image inspection device.

[0023] FIG. **3** is a functional block diagram within the DSP.

[0024] FIG. **4** is a flowchart showing an example of the procedure during the setting of the image inspection device.

[0025] FIG. **5** is a flowchart showing an example of the procedure during the setting of the inspection tool.

[0026] FIG. **6** is a flowchart showing an example of the procedure during the execution of the inspection.

[0027] FIG. **7** is a diagram showing the processing concept of the AI-OCR tool.

[0028] FIG. **8** is a diagram explaining the character types in pre-learning.

[0029] FIG. **9** is a diagram showing the character type output unit at the completion of pre-learning.

[0030] FIG. **10** is a diagram showing the character type output unit at the completion of on-site learning.

[0031] FIG. **11** is a diagram showing a specific example of character recognition processing.

[0032] FIG. **12** is a diagram showing a specific example of dictionary registration processing.

[0033] FIG. **13** is a diagram explaining the case of additional learning of the same character that appears different.

[0034] FIG. **14** is a flowchart showing an example of the procedure for re-learning after the operation of the image inspection device.

[0035] FIG. **15** is a diagram showing an example of the operation result display screen.

[0036] FIG. **16** is a diagram showing an example of the additional learning window display.

[0037] FIG. **17** is a diagram showing an example of the screen displayed during additional learning.

[0038] FIG. **18** is a diagram showing an example of the character type selection window display.

[0039] FIG. **19** is a diagram corresponding to FIG. **17** showing the state where the character type is selected.

[0040] FIG. **20** is a diagram showing an example of the screen displayed when adding unregistered character types for additional learning.

[0041] FIG. **21** is a diagram showing an example of the screen displayed when registering character types in the user dictionary.

[0042] FIG. **22** is a diagram showing an example of the window for newly registering character types.

[0043] FIG. **23** is a diagram corresponding to FIG. **19** showing the newly registered character types.

[0044] FIG. **24** is a diagram showing an example of the screen displayed before starting additional learning.

[0045] FIG. **25** is a diagram showing an example of the screen displayed when confirming the results of additional learning.

[0046] FIG. **26** is a diagram showing an example of the screen displayed during operation when inspecting the date.

[0047] FIG. **27** is a diagram showing an example of the selection window that accepts the selection of the OCR mode.

[0048] FIG. **28** is a diagram showing an example of the screen displayed when specifying the template.

[0049] FIG. **29** is a diagram showing an example of the window for setting judgment conditions.

[0050] FIG. **30** is a diagram showing an example of the window for setting the date and time offset.

[0051] FIG. **31** is a diagram explaining the case of changing the master string for each imaging.

[0052] FIG. **32** is a diagram showing an example of the screen displayed when performing custom settings.

[0053] FIG. **33** is a diagram showing an example of the format setting window.

[0054] FIG. **34** is a diagram corresponding to FIG. **33** showing the case when separated by elements.

[0055] FIG. **35** is a diagram showing the screen displayed when setting the content of the elements.

[0056] FIG. **36** is a diagram showing the screen where the first selection window showing the options for the content of the elements is displayed.

[0057] FIG. **37** is a diagram showing the screen where the second selection window showing the options for the content of the elements is displayed.

[0058] FIG. **38** is a diagram showing an example of the count up/down setting window.

[0059] FIG. **39** is a diagram showing an example of the window for replacement settings.

[0060] FIG. **40** is a diagram showing an example of the linking window to link the notation of early, middle, and late parts of the month with the calendar.

[0061] FIG. **41** is a diagram showing an example of the batch input window.

[0062] FIG. **42** is a diagram showing the screen displayed when an image containing a string arranged in an arc shape is input.

[0063] FIG. **43** is a diagram corresponding to FIG. **42** showing the case when the phase of the string arranged in an arc shape changes.

[0064] FIG. **44** is a diagram showing an example of the arc setting window.

[0065] FIG. **45** is a diagram showing the screen displayed when performing additional learning using a test image with different phases of the string.

[0066] FIG. **46** is a diagram showing an example of the screen displayed during operation when inspecting a string arranged in an arc shape.

[0067] FIG. **47** is a diagram corresponding to FIG. **46** showing the case when part of the string arranged in an arc shape is missing.

[0068] FIG. **48** is a diagram showing an example of the additional learning confirmation window.

[0069] FIG. **49** is a diagram explaining the case when the box enclosing the characters to be learned during additional learning is moved.

DETAILED DESCRIPTION

[0070] The following describes in detail the embodiments of the present invention based on the drawings. The description of the preferred embodiments below is essentially illustrative and is not intended to limit the present invention, its applications, or its uses.

[0071] FIG. **1** is a diagram explaining the operation of the image inspection device S according to an embodiment of the present invention. The image inspection device S captures an image of the work W conveyed by the conveying means A according to the imaging settings, acquires a work image, and judges the acquired work image according to the judgment settings to output the inspection result using the judgment result as a sensor output to an external device. The external device can include, for example, a Programmable Logic Controller (PLC) **5**, but it may also be a device other than PLC **5**. The PLC **5** controls the conveying means A to separate the storage destination of the work W based on the received inspection result. The following explanation will describe the case where the external device is PLC **5**. Note that the work W may also be a work that is not conveyed by the conveying means A.

[0072] The image inspection device S is equipped with an imaging unit **1** for capturing the work W, a control unit **2** to which image data captured by the imaging unit **1** is input, a PC (personal computer) **3** for setting the image inspection device S, and a display device **4** for displaying the setting screen, selection screen, work images, inspection results, and the like. The control unit **2** is capable of executing a trained model that performs a classification task into multiple character type classes for recognizing characters in an image area that is a part of the input image data. The control unit **2** executes sensor output to the PLC **5** according to the character recognition results from the trained model.

[0073] The image inspection device S is sometimes used to inspect the work W from various angles at various points of a manufacturing device or manufacturing line. Therefore, there may be multiple image inspection devices S installed in a single manufacturing device or manufacturing line, and it is conceivable that sufficient installation space and power supply cannot be secured. Thus, the image inspection device S requires miniaturization to fit the installation space and power saving to match the power supply, and to satisfy these requirements, the image inspection device S according to this embodiment is configured without a GPU. In other words, the control unit **2** is equipped with a pre-trained model that has been trained to a level capable of basic character recognition, but it is possible to achieve the desired classification accuracy without the user performing advanced additional learning that would recommend GPU usage. Furthermore, the fact that the user does not need to perform advanced learning means that the user does not need to prepare a GPU tailored for learning, which can shorten the time required for learning. It is also possible to install and operate a single image inspection device S on a manufacturing device or manufacturing line. Additionally, the image inspection device S can also be referred to as an image sensor.

[0074] (Structure of Imaging Unit) Imaging unit **1** is configured separately from control unit **2** and is installed so that it can capture the workpiece W from a desired direction. The workpiece W is sequentially conveyed by conveying means A into the imaging field of Imaging Unit **1**.

[0075] As shown in FIG. **2**, the imaging unit **1** includes a lighting module **10** for illuminating the work W and a camera module **11** for capturing the work W illuminated by the lighting module **10**.

[0076] The lighting module **10** includes an LED (light emitting diode) **10***a* that irradiates light toward the work W and an LED driver **10***b* that controls the light amount and light emission timing of the LED **10***a*. The LED driver **10***b* is connected to the head communication unit **20** of the control unit **2** (described later) and is controlled by the control unit **2**'s control unit **21** (described later).

[0077] The camera module **11** includes an AF motor **11***a* and an imaging board **11***b*. The AF motor **11***a* is a component that automatically focuses on the work W by driving a focusing lens of an optical system (not shown). The method of automatic focus is not particularly limited, and examples such as the contrast method can be mentioned.

[0078] The imaging board **11***b* is equipped with a CMOS sensor **11***c*, an FPGA **11***d*, and a DSP **11***e*. The CMOS sensor

11*c* is an image sensor that receives reflected light reflected from the work W, which is irradiated by the LED **10***a*. This CMOS sensor **11***c* is connected to the head communication unit **20** of the control unit **2** and is controlled by the control unit **21** of the control unit **2** to perform exposure processing for a predetermined time at a predetermined timing.

[0079] The FPGA **11***d* is a processing device capable of changing the internal processing content. The DSP **11***e* is a signal processing device. The light reception amount signal of the light receiving element possessed by the CMOS sensor **11***c* is output to the FPGA **11***d* for processing, and is also output to the DSP **11***e* for processing. The processing by the FPGA **11***d* and DSP **11***e* is not particularly limited, but various filter processing can be mentioned as examples. The image data processed by the FPGA **11***d* and DSP **11***e* is transmitted from the imaging unit **1** to the control unit **2**.

[0080] The imaging unit **1** and the control unit **2** are connected via the communication cable **6**. Therefore, the control unit **2** can be installed at a location away from the installation location of the imaging unit **1**.

[0081] (Structure of PC) PC**3** is composed of a general-purpose personal computer or the like. In this example, PC**3** becomes usable by installing a predetermined program on the personal computer. PC**3** includes input devices such as a keyboard **3***a* and a mouse (not shown). The user of the image inspection device S can perform setting operations and selection operations of the image inspection device S by operating the input devices of PC**3**. Specific setting operations and selection operations will be described later.

[0082] The communication board **22** of PC**3** and control unit **2** is connected to each other in a communicable manner, and information based on the setting operation by the user is transmitted from PC**3** to control unit **2**. In addition, image data of work W and inspection results output from control unit **2** can be received by PC**3**. PC**3** and control unit **2** are connected via communication cable **7**. Therefore, PC**3** can be installed at a location away from the installation location of control unit **2**.

[0083] (Structure of Display Device **4**) The display device **4** is composed of, for example, a liquid crystal display or an organic EL display. In this example, the display device **4** includes a touch panel **4***a*. The touch panel **4***a* is a member capable of detecting operations by the user's finger. The form of the touch panel **4***a* is not particularly limited, and examples include capacitive type and infrared type. The display device **4** and the communication board **22** of the control unit **2** are connected to each other in a manner that allows mutual communication. The operation information of the touch panel **4***a* by the user is transmitted from the display device **4** to the control unit **2**. In addition, image data of the work W output from the control unit **2** can be received by the display device **4**. The display device **4** and the control unit **2** are connected via a communication cable **7**. Therefore, the display device **4** can be installed at a location away from the installation location of the control unit **2**.

[0084] Moreover, PC**3** and display device **4** may be configured as a single unit. For example, display device **4** may be configured with the display device possessed by PC**3**. In this case, the main body of PC**3** and display device **4** may be integrated or may be separate. In addition, in this example, communication board **22** and PLC **5** are connected via communication cable **7**.

[0085] (Configuration of Control Unit **2**) As shown in FIG. **2**, the control unit **2** includes a head communication unit **20**, a control unit **21**, a communication board **22**, a power supply **23**, a connector board **24**, an I/O board **25**, and a storage device (storage unit) **26**. The head communication unit **20** is connected to the control unit **21** and is the part that performs mutual communication between the control unit **21** and the imaging unit **1**. The control signal of the imaging unit **1** output from the control unit **21** is transmitted to the imaging unit **1** via the head communication unit **20**. The control signal of the imaging unit **1** includes a signal that controls the light emission timing and light emission amount of the LED **10***a*, and a signal that controls the AF motor **11***a* and the imaging board **11***b*. In addition, the image data obtained by the imaging unit **1** is transmitted to the control unit **21** via the head communication unit **20** after being output from the imaging unit **1**.

[0086] The control unit **21** includes a DSP **21***a* and an FPGA **21***b* that perform various signal processing, an accelerator **21***c* for speeding up processing, and a memory **21***d* composed of RAM, ROM, etc. The specific configuration of the control unit **21** will be described later.

[0087] The communication board **22** is connected to the control unit **21** and is a component that performs mutual communication between the control unit **21**, PC**3**, display device **4**, and PLC **5**.

[0088] The connector board **24** includes a power interface **24***a*. The power interface **24***a* is connected to a power cable (not shown) for supplying power from the outside. The connector board **24** is connected to the power supply **23**, and the power supplied to the power interface **24***a* from the outside is adjusted to a predetermined voltage by the power supply **23** before being supplied to the control unit **21**. The power supplied to the control unit **21** is supplied to the imaging unit **1** via the head communication unit **20**.

[0089] The I/O board **25** is connected to the control unit **21**. The inspection results output from the control unit **21** are input to the PLC **5** via the I/O board **25**.

[0090] (Details of DSP**21***a*) FIG. **3** is a functional block diagram of the control unit **2** having the control section **21**. The control section **21** includes an imaging setting unit **100**, an inspection setting unit **200**, and an inspection execution unit **400**.

[0091] The imaging setting unit **100** is a part that sets the imaging setting parameters and reflects the set imaging setting parameters during the imaging of the work W. The imaging setting parameters include multiple parameters such as the timing of illumination by the illumination module **10**, brightness (light emission amount), exposure time by the camera module **11**, and focus (focal position) of the camera module **11**. When setting the image inspection device S, the imaging setting unit **100** displays a GUI (graphical user interface) related to the setting of the imaging setting parameters on the display device **4**. Although not shown, the GUI related to the setting of the imaging setting parameters has areas where the brightness of the illumination, exposure time, focus, etc. can be set individually. When the user inputs each parameter on the GUI using a touch panel **4***a* or a keyboard **3***a*, the imaging setting unit **100** accepts the setting operation by the user and outputs each parameter to, for example, the storage device **26** to store it in the corresponding storage device **26**. It is possible to read each parameter from the storage device **26** as needed.

[0092] When acquiring image data of the work W, the imaging setting unit **100** outputs the setting data including the imaging setting parameters to the camera module **11**.

When the camera module **11** receives the setting data, it sets the imaging setting parameters included in the received setting data to be reflected during imaging within the camera module **11**. When the camera module **11** receives the imaging trigger signal, it illuminates the work W according to the imaging setting parameters and captures the image data of the work W.

[0093] The inspection setting unit **200** includes a tool setting unit **201**, a master image registration unit **220**, and an inspection condition setting unit **230**. The tool setting unit **201** has a tool selection unit **202**, a parameter setting unit **205**, and a learning tool setting unit **305**. The tool selection unit **202** is a part that allows the user to select the tool set by the user. When setting the image inspection device S, the tool selection unit **202** displays a GUI related to the selection of tools on the display device **4**. Although not shown, the GUI related to the selection of tools has an area where the user can select the desired tool from multiple tools. When the user selects any tool on the GUI using a touch panel **4***a* or a keyboard **3***a*, the tool selection unit **202** accepts the selection operation by the user and outputs the selected tool to, for example, the storage device **26** to store it in the corresponding storage device **26**. It is possible to read the selected tool from the storage device **26** as needed.

[0094] When the tool selected in the tool selection unit **202** is a rule-based tool, the information regarding the tool selected in the tool selection unit **202** is output to the parameter setting unit **205** as selected tool information. When setting the image inspection device S, the parameter setting unit **205** displays a GUI (Graphical User Interface) related to the setting of tool parameters on the display device **4**. The tool parameters are parameters that can be set for each tool. When the user sets the tool parameters on the GUI using a touch panel **4***a* or a keyboard **3***a*, the parameter setting unit **205** accepts the setting operation by that user and outputs the tool parameters to, for example, the storage device **26** to store them in the storage device **26**. It is possible to read the tool parameters from the storage device **26** as needed. The learning tool setting unit **305** will be described later.

[0095] The master image registration unit **220** is a part that registers the captured image I**1** as the master image I**2**. Specifically, the master image registration unit **220** presents the captured image I**1** to the user by incorporating it into the GUI and displaying it on the display device **4**.

[0096] When the user wants to register the captured image I**1** displayed on the display device **4** as the master image I**2**, they perform the registration operation using a touch panel **4***a* or a keyboard **3***a*. The master image registration unit **220** registers the captured image I**1** for which the registration operation has been performed by the user as the master image I**2**, and outputs it to, for example, the storage device **26** to store it in the storage device **26**.

[0097] The master image registration unit **220** has an inspection window setting unit **221**. The inspection window setting unit **221** receives instructions regarding the position, range, shape, etc. of the inspection window for the captured image I**1** registered as the master image I**2**, for example. Specifically, the inspection window setting unit **221** displays a GUI for setting the inspection window on the display device **4**. When the user inputs the position, range, shape, etc. of the inspection window on the GUI using a touch panel **4***a* or a keyboard **3***a*, the inspection window setting unit **221** accepts the setting operation by the user and outputs it as information regarding the inspection window to, for example, the storage device **26**, and stores it in the storage device **26**. The inspection window setting unit **221** reflects the setting of the inspection range based on the positional relationship of the inspection window to the captured image I**1**.

[0098] The inspection condition setting unit **230** is a part that sets the output conditions for inspection results, that is, under what conditions the judgment results of each tool used for inspection will output a predetermined inspection result. The inspection condition setting unit **230** displays a GUI that allows the selection of tools used for inspection and the setting of output conditions on the display device **4**. Although not shown, this GUI has an area where any tool can be selected from rule-based tools or learning tools. When the user selects a tool on the GUI using a touch panel **4***a* or a keyboard **3***a*, the inspection condition setting unit **230** accepts the selection operation by the user. Additionally, this GUI has an area where output conditions can be set. When the user sets the output conditions on the GUI using a touch panel **4***a* or a keyboard **3***a*, the inspection condition setting unit **230** accepts the output condition setting operation by the user. As output conditions, for example, conditions such as "how many detected objects are required for the inspection result to be output as 'Good'" when the tool is the AI object detection tool T**2** described later or "under what conditions must the string meet for the inspection result to be output as 'Good'" when the judgment tool is the AI-OCR tool T**3** can be cited.

[0099] The learning tool setting unit **305** includes a learning data setting unit **310** and a classifier update unit **315**. The learning data setting unit **310** is a part that accepts settings for handling the captured image I**1** as learning data D**1** and reflects those settings. The settings for handling the captured image I**1** as learning data D**1** include the setting of label information. Specifically, the learning data setting unit **310** includes a learning image selection unit **310***a*, a learning data generation unit **310***b*, and a label information setting unit **310***c*.

[0100] The learning image selection unit **310***a* is a part that selects the captured image I**1** to be treated as a learning image. The learning image selection unit **310***a* accepts image selection operations by users using a touch panel **4***a* or a keyboard **3***a* on the GUI and outputs the image data of the selected learning image, which is the learning image I**3**, to the learning data generation unit **310***b*. The image selected by the learning image selection unit **310***a* may be an image other than the captured image I**1**. Furthermore, it may be configured such that the learning image I**3** is selected automatically without accepting selection operations from the user.

[0101] The label information setting unit **310***c* displays a GUI incorporating the learning image **13** selected by the learning image selection unit **310***a* on the display device **4**, accepts designation operations related to the setting of label information, and sets the label information based on the information designated by the operation.

[0102] The learning data generation unit **310***b* generates learning data D**1** based on learning image data and label information. The learning data generation unit **310***b* acquires learning image data from the learning image selection unit **310***a*, acquires label information from the label information setting unit **310***c*, and outputs the generated learning data D**1**

to the classifier update unit **315**. In this way, the control unit **21** functions as the learning data generation unit **310***b* that generates learning data D**1**.

[0103] The information acquired by the learning data generation unit **310***b* for generating the learning data D**1** varies depending on the type of learning tool that the learning data D**1** is used for. As will be described in detail later, for example, when generating the learning data D**1** for the learning of the AI-OCR tool T**3**, the learning data generation unit **310***b* acquires learning image data, and as label information, specified position information indicating the relative position of characters in the learning image, specified character type information indicating the character type of the character, and specified size information indicating the size of the character in the image.

[0104] The learning data setting unit **310** may change the selection method of learning images and the setting method of label information according to the type of learning tool that uses the learning data D**1** reflecting the settings of the learning data setting unit **310**.

[0105] When the learning tool T**1** determines based on the feature trend of the entire image area included in the inspection window set by the inspection window setting unit **221**, the entire image area corresponding to the inspection window among the selected learning image I**3** is regarded as the image area to which a label is assigned. In other words, the setting of the position to which the label is assigned by the label information setting unit **310***c* is unnecessary. In this case, the label information setting unit **310***c* can set the label information by only accepting the specification of the label, thereby reducing the operational procedures related to the setting of the learning data D**1**. The specification of the label here corresponds to the specification of the class when the label is a class label indicating the class.

[0106] Furthermore, in the above case, when the judgment result of the tool is treated as the inspection result (for example, "Good" or "Defective"), it becomes easier for the user to grasp the features of the images that should be classified into the corresponding class. In this case, the learning image selection unit **310***a* may accept image selection operations while fixing the class of the class label to be assigned. When the learning image selection unit **310***a* accepts the selection operation of the learning image I**3** while displaying a GUI that guides, for example, "Please select the image you want to classify as the first class 'Good'" on the display device **4**, the image area to which the label is assigned is determined by the inspection window, and the label information setting unit **310***c* can set the label information as if the specified image area has been designated as the first class "Good" without accepting an operation to specify the class. Since the label information can be set based on the fixed class, the operation procedure related to the setting of the learning data D**1** is reduced.

[0107] The learning tool, which is an AI object detection tool T**2** that detects the target object taught by the user from the image area included in the inspection window set by the inspection window setting unit **221**, accepts the specification operation of the position on the image and the specification operation of the label to be assigned to that position by the label information setting unit **310***c*. The learning image I**3** is an image that contains the target object to be detected, and includes an image area where the target object is present and a background area where the target object is absent. Since the image area where the target object is present and the background area where the target object is absent should be assigned different class labels, it is necessary to accept the specification of the position where the label will be assigned. The label information setting unit **310***c* outputs a combination of specified position information indicating the position and specified class information based on the class label assigned to that position as label information to the learning data generation unit **310***b*. In this way, the user assigns the class label of class "target object (foreground)" to a predetermined position on the image, but the operation to specify the class may be omitted. Since the AI object detection tool T**2** is a learning tool for detecting the target object, it is estimated that the position specified by the user on the image is where class label of class "target object" should be assigned. The label information setting unit **310***c* may omit accepting operation to specify class by accepting specification of position on the image while displaying guidance such as "Please specify the position of the target object in the image."

[0108] The learning tool that performs recognition of characters in the image area included in the inspection window set by the inspection window setting unit **211**, namely, the AI-OCR tool T**3**, also accepts position specification on the image by the label information setting unit **310***c*, similar to the AI object detection tool T**2**. In the AI-OCR tool T**3**, in addition to detecting characters, it also identifies the character type of the detected characters, so the label information setting unit **310***c* accepts operations to specify the character type as label specifications. By accepting operations to specify the character type, the label information setting unit **310***c* specifies two classes: the class "any character" and the character type class, and the specified character type information includes the class label of the class "any character" and the class label of the character type class. The label information setting unit **310***c* outputs the combination of the specified position information and the specified character type information as label information to the learning data generation unit **310***b*.

[0109] The label information output by the label information setting unit **310***c* is not limited to specified position information and specified class information, and may include size information and angle information. The size information and angle information may be specified by size labels and angle labels separately provided by the user, but when the label information setting unit **310***c* allows the user to specify a position with a rectangular boundary box, the specified size information and specified angle information can be obtained from that boundary box. The specified size information and specified angle information may be used for updating the classifier.

[0110] The setting of learning data D**1** for the AI-OCR tool T**2** in this embodiment uses positioning information, specified size information, and specified character type information. As will be described in detail later, in this embodiment, the specified size information is incorporated into the specified character type information. In other words, the character type with the specified size information is treated as a single character type class. At this time, the position on the image is specified using a boundary box on the GUI, and the combination of the size corresponding to the boundary box and the specified character type class assigned to that position is used to identify the character type class corresponding to the specified position by the label information setting unit **310***c*. Therefore, the label information in the

case of setting the learning data D1 for the AI-OCR tool T2 is a combination of the position in the captured image and the specified character type class for that position.

[0111] The classifier update unit **315** receives the learning data D1 generated by the learning data generation unit **310***b* and executes the update of the classifier based on the learning data D1 using a method that includes machine learning technique, and has a classification unit update part **315***a* and a class addition part **315***b*. In this embodiment, the classifier update unit **315** functions as a learning execution unit, and therefore the control unit **21** also functions as a learning execution unit that executes learning based on the learning data, controlling on-site learning to the pre-trained model.

[0112] Here, pre-training refers to the process in which the provider of the image inspection device S creates a model using machine learning techniques before providing the product to the user. Therefore, the pre-trained model refers to the model at the time of providing the image inspection device S by the provider. Furthermore, on-site learning refers to the process in which a user who has received the image inspection device S presents learning data and creates or modifies a model using techniques including machine learning.

[0113] The classifier update unit **315** updates the classifier used in inspection by implementing a predetermined update method based on the received learning data D1. In other words, the classifier update unit **315** performs learning using the learning data D1. The classifier to be updated varies depending on the selected learning tool. The classifier update unit **315** inputs the image data contained in the learning data D1 into the feature extraction unit **510** of the classifier to be updated and updates the classifier using a method that includes a machine learning technique utilizing the extracted features (feature vector or feature map) and the label information corresponding to the image data.

[0114] The classification unit update unit **315***a* updates the classification unit **520** of the determiner to be updated, which classifies image data into classes. Specifically, the classification unit update unit **315***a* executes the feature extraction unit **510** of the determiner to be updated, inputs the learning image data of the learning data D1, and obtains the feature F (feature vector). As a result, the learning data group is treated as a group of "combinations of feature vectors and class labels corresponding to each feature vector." Based on this combination group, the boundary surface is generated so that each class specified by the class label is distinguished in the feature space where the feature vector of feature F is mapped. When additional learning data is present, the boundary surface is readjusted so that the additional feature F in the feature space is classified into the class associated with the additional feature F.

[0115] If the classifier updated by the classifier update unit **315** is a classifier executed by the learning tool T1, the classification unit update unit **315***a* executes the feature extraction unit **510** to obtain feature F1 from the entire learning image data included in the learning data D1. Then, the classification unit update unit **315***a* updates the image classification unit, which is a classifier **520** that classifies image data into classes set by the user. The image classification unit is an SVM (Support Vector Machine) as a linear classifier.

[0116] When the classifier updated by the classifier update unit **315** is a classifier executed by the AI object detection tool T2, similarly to when it is a classifier executed by the learning tool T1, the classification unit update unit **315***a* updates the image region classification unit. The image region classification unit is also a linear classifier, similar to the image classification unit. The point of difference compared to when the classifier update unit **315** updates a classifier executed by the learning tool T1 is that the feature extraction unit **510** inputs a part of the region image of the learning image data to obtain feature F2 (feature vector), and otherwise updates the classification unit in the same manner as in the case of the learning tool T1.

[0117] The Class Addition Unit **315***b* updates the target classifier to be able to classify into an additional class specified by the learning data D1, in addition to the existing classes that can be classified before the update. Typically, since the classification unit optimizes parameters in comparison with other classes, it is necessary to learn using at least one image data for each target class. The parameter update by the Classification Unit Update Unit **315***a* uses at least one image data for each target class. In on-site learning, there is a limit to the amount of image data collected, and if the parameters of the classification unit are updated only with image data that does not cover all classes, it may be possible to classify the class of the presented image, but the accuracy of classification for other classes and the classification accuracy of images that should belong to other classes may decrease. Furthermore, even if all classes can be covered, it is difficult to prepare an equivalent amount of image data for on-site learning as in pre-training, which leads to a decrease in classification accuracy for at least the existing classes. Additionally, learning by the Classification Unit Update Unit **315***a* tends to require a large amount of computation when there are many target classes, resulting in a high learning load. To reduce the learning load and increase the adaptability to the additional classes added in additional learning, the Class Addition Unit **315***b* updates the parameters by labeling the arrangement of extracted features obtained by the classification unit before the update. In this embodiment, when the Classifier Update Unit **315** updates the classifier of the AI-OCR Tool T3, the Class Addition Unit **315***b* updates the classifier.

[0118] The class addition unit **315***b* inputs a part of the area image of the learning image data into the feature extraction unit **510** to obtain the feature F3, which is similar to the case where the classifier of the AI object detection tool T2 is updated. The difference from the case where the AI object detection tool T2 is updated is that the classifier's judgment unit **520** is the character type output unit **523** obtained by the metric learning method in the pre-training. More specifically, the character type output unit **523** is pre-trained so that the distances between feature vectors of the same character type class are small and the distances between feature vectors of different character type classes are large in the embedding space. At this time, representative vectors are defined as representative feature vectors for each character type class, and the character type output unit **523** classifies the image data into the character type class of the representative vector that is close in distance to the feature vector of the image data and outputs the classification result. In the character type output unit **523**, which has undergone such pre-training, the feature vector that should be classified into a new character type class based on the learning data D1 is arranged in the embedding space to be separated from the representative vector of the existing character type class

when it is a different character type from the existing character type class. The class addition unit **315***b* utilizes this arrangement of feature vectors to define the feature F**3** extracted from the learning data D**1** as a new representative vector. That is, the calculation parameters up to the arrangement of the feature F (feature vector) in the embedding space remain the same, enabling classification into a new character type class. In addition, the class addition unit **315***b* adds a class that combines the specified size and specified character type among the label information of the learning data, that is, a new character type class "the character type including the specified size".

[0119] The inspection execution unit **400** includes a rule judgment unit **402**, a learning tool execution unit **403**, and an inspection result output unit **410**.

[0120] The rule judgment unit **402** is a part that makes a judgment based on the inspection tool when a rule-based tool is included in the inspection tools used for inspection, for the captured image I**1** of the inspection target. The parameters set by the parameter setting unit **205** are used.

[0121] The learning tool execution unit **403** is a part that executes the classifier when the learning tool is included in the inspection tool used for inspection and outputs the judgment result for the captured image I**1** of the inspection target. The classifier includes a feature extraction unit **510** and a judgment unit **520**.

[0122] The feature extraction unit **510** is composed of, for example, a convolutional neural network. The feature extraction unit **510** is a part that extracts features indicating the characteristics of the input image data from the image data, and can also extract features for any position in the input image data. The feature extraction unit **510** is a part that is pre-trained to extract features corresponding to each learning tool and has parameters used in the process of extracting feature F from the image data.

[0123] The feature extraction unit **510** is capable of extracting feature F in a format corresponding to the learning tool. For example, when the learning tool T**1** is executed, image data (captured image I**1**) is input to the feature extraction unit **510**, and a multidimensional feature vector is obtained as feature F. Furthermore, when a judgment utilizing the spatial information of the input image is made, image data is input to the feature extraction unit **510**, and a feature map is obtained in which a feature vector is calculated for each convolution pixel corresponding to a certain range of pixel areas in the input image data.

[0124] The judgment unit **520** is a part that outputs judgment results based on the input feature F (feature vector or feature map). The judgment unit **520** executed in the learning tool execution unit varies according to the learning tool, and at least one of the image classification unit, the image region classification unit, the character type output unit **523**, the size output unit **524**, and the image region angle output unit **525** is executed.

[0125] The image classification unit classifies the feature quantity F**4** obtained from the feature extraction unit **510**. The feature quantity F**4** is a feature vector. The image classification unit outputs information indicating which class the image data corresponding to the feature quantity F**4** belongs to. In the execution of the learning tool T**1**, the image classification unit is executed, and if the learning tool T**1** is set to classify into the first class "good" and the second class "defective" by the learning tool setting unit **305**, the image classification unit outputs information indicating whether the captured image I**1** belongs to the first class or the second class based on the feature quantity F**4** obtained from the captured image I**1**.

[0126] The image area classification unit classifies each convolution pixel of the feature map based on the feature quantity F**5** obtained from the feature extraction unit **510**. Since the image area classification unit classifies each convolution pixel of the feature map, it can output where in the captured image I**1** the image area classified into the specified class exists, based on the spatial information possessed by the feature map. When the image area classification unit is executed in the execution of the AI object detection tool T**2**, the convolution pixels of the feature map F**5** are classified as either the first class "object (foreground)" or the second class "background" by the image area classification unit. Therefore, based on this classification result, it can be determined where in the captured image I**1** corresponding to the feature map F**5** the area image belonging to the first class "foreground" exists, that is, whether the work W as the object exists.

[0127] The image area classification unit executed in the operation of the AI-OCR tool T**3** classifies each convolution pixel of the feature map as feature quantity F**6** into the first class "foreground" class and the second class "background". Based on this classification result, it can be determined where the character image area is in the captured image I**1** corresponding to the feature quantity F**6**.

[0128] The character type output unit **523** is executed in the execution of the AI-OCR tool T**3**. The character type output unit **523** outputs the classification result of the character type class based on the feature quantity F**7** obtained from the feature extraction unit **510**. Since the feature quantity F**7** is a feature map, the character type output unit **523** can determine where in the captured image I**1** corresponding to the feature quantity F**7** there is a character image area belonging to any character type class. When classified into an additional character type class by the character type output unit **523**, the classification result allows us to obtain as a determination result where in the image data corresponding to the input feature map, what type of character image exists, and what size it is.

[0129] The size output unit **524** is executed when the AI-OCR tool T**3** is executed, and outputs the size of the corresponding image area based on the feature quantity F**8** output from the feature extraction unit **510**. The feature quantity F**8** is a feature map. The size output unit **524** executed in the execution of the AI-OCR tool T**3** outputs the size of the character image area corresponding to each pixel of the feature map.

[0130] The image region angle output unit **525** outputs information on the angle at which the corresponding image region exists based on the feature quantity F**9** output from the feature extraction unit **510**. The image region angle output unit **525**, which is executed in the execution of the AI object detection tool T**2**, outputs angle information when the image region of the input data corresponding to each pixel of the feature map as the feature quantity F**9** is the image region of the work W.

[0131] The inspection result output unit **410** generates and outputs inspection results based on the judgment results obtained from the execution of the judgment unit **520** according to the output conditions set by the inspection condition setting unit **230**. For example, if the tool used for inspection is only the learning tool T**1**, and the output

condition is set to take the judgment result of the learning tool T**1** as the inspection result, the inspection result output unit **410** obtains the class classification results of the first class "Good" and the second class "Defective" as the judgment results for the image data of the captured image I**1**. Then, the inspection result output unit **410** generates an inspection result indicating that the captured image I**1** is an image of a good product when the obtained judgment result is the first class "Good", and outputs the inspection result from the I/O board **25** to the PLC or the like.

[0132] Inspection condition setting unit **230** sets an inspection using AI object detection tool T**2**, and if the output condition is that "work W is detected one or more times" and outputs "ON" as the inspection result, the inspection result output unit **410** obtains the classification result from the image area classification unit **521** as the judgment result, and displays as the judgment result where and at what angle work W exists in the image data corresponding to the input feature quantity F**2**. Then, the inspection result output unit **410** generates the inspection result based on the number of work W shown in the judgment result in the image data, displays the area corresponding to the detected work W on the target image data, and outputs the inspection result to PLC or the like. In this example, the number of work W to be detected is specified as the output condition, but parameters such as the number of work W may also be set as conditions for the judgment of AI object detection tool T**2**. Furthermore, if the angle of the image area is estimated in the judgment based on AI object detection tool T**2**, conditions using angles such as "the detected work W is within **+15**° of the master image's work W" may be set as output conditions.

[0133] The AI object detection tool T**2** can register multiple types of target objects for object detection. For example, by registering the first target object, work W**1**, and the second target object, work W**2**, which has a different shape, color, and size from the first target object, the inspection result generation unit **332***a* obtains the judgment result of where work WI exists in the image data and at what angle, as well as the judgment result of where work W**2** exists in the image data and at what angle.

[0134] Inspection condition setting unit **230** sets an inspection using AI-OCR tool T**3**, and when the output condition "the characters following 'best before date' indicate a date within three days from the inspection date" is set, the inspection result output unit **410** obtains a judgment result indicating where in the image and what character image exists. The inspection result output unit **410** generates the inspection result based on the character information indicated in the judgment result, displays the area corresponding to the detected character image on the target image data and the character type corresponding to that area, and outputs the inspection result to a PLC or the like. At this time, for the existing character type class, the inspection result output unit **410** obtains a judgment result indicating where in the image, what character image exists, and what size it is, based on the classification result by the character type output unit **523** and the size output unit **524**, for the image data of the captured image I**1** corresponding to the input feature quantity F. For the additional character type class, the inspection result output unit **410** obtains a judgment result indicating where in the image, what character image exists, and what size it is, based on the classification result by the character type output unit **523**.

[0135] The inspection result output unit **410** may generate and output inspection results by combining multiple inspection tools, including rule-based tools and learning tools. For example, if the learning tool T**1** determines the first class as "good," and the AI object detection tool T**2** determines that there are two target objects in the image, and the AI-OCR tool T**3** determines that the expiration date is correctly printed on a predetermined part of the target object detected by the AI object detection tool T**2**, it can also output the inspection result "ON."

[0136] The inspection result output unit **410** also has an additional learning image designation unit **415**. Based on the judgment results obtained from the judgment unit **520** and the inspection results generated based on the judgment results, a GUI that accepts the designation of the learning image I**3** to be added as a target for on-site learning can be displayed on the display device **4**. The user can specify the learning image using the additional learning image designation unit **415**. When an image is specified by the additional learning image designation unit **415**, information related to the specified image is output to the learning data setting unit **310**. The learning data setting unit **310** treats the image specified by the additional learning image designation unit **415** in the same manner as the learning image I**3** selected by the learning image selection unit **310***a*. In other words, the learning data generation unit **310***b* generates learning data D**1** based on the learning image data of the learning image I**3** specified by the additional learning image designation unit **415** and the label information set by the label information setting unit **310***c*.

(When Setting the Image Inspection Device)

[0137] FIG. **4** is a flowchart showing the control of the control unit **21** during the setting of the image inspection device S. In step SA**1** after the start, the control unit **21** receives the setting of imaging setting parameters from the user via the imaging setting unit **100** and sets the imaging setting parameters. In step SA**2**, the imaging setting parameters set in step SA**1** are applied to execute imaging by the imaging unit **1**. The image data acquired by the imaging unit **1** is stored in the storage unit **26** and treated as the master image I**2** and the learning image I**3**.

[0138] In the inspection setting of step SA**3**, input related to the image inspection settings for the captured image I**1** is accepted. In step SA**4**, input of signals from external sources, output of signals to external sources, and communication settings are performed.

[0139] FIG. **5** is a flowchart showing the details of step SA**3** when using a learning tool as an inspection tool. In step SB**1**, the control unit **21** registers the image obtained in step SA**2** shown in FIG. **4** as the master image I**2** by the master image registration unit **220**. In step SB**2**, the inspection window setting unit **221** sets the inspection range on the master image I**2** registered in step SB**1**.

[0140] In step SB**3**, the control unit **21** selects the learning image I**2** by the learning image selection unit **310***a*.

[0141] In step SB**4**, the control unit **21** sets the settings related to the judgment of the learning tool. More specifically, label information is set by the label information setting unit **310***c*, learning data D**1** is generated based on the label information by the learning data generation unit **310***b*, and the classifier is updated based on the learning data D**1** by the classifier update unit **315**. For example, in the learning tool T**1**, when the user is asked to select image data belonging to

a class in a state where the class is determined, the user's selection of image data is both the acceptance of the selection of the learning image I3 in step SB3 and the acceptance of input for the judgment setting in step SB4. Thus, depending on how the input from the user is accepted, steps SB3 and SB4 may be executed simultaneously.

[0142] In the case where the label assignment target is not specified in conjunction with the selection of the learning image I3, such as in the AI-OCR tool T3, after the learning image I3 is selected by the learning image selection unit **310***a* in step SB3, the label information setting unit **310***c* uses the selected learning image I3 to accept user designation related to step SB4. However, by using the classifier in the setting of step SB4, the acceptance of user designation can be omitted. For example, a class label may be assigned to the learning image selected in step SB3 using an existing classifier, and learning data is generated based on the assigned class label. In such a case, steps SB3 and SB4 may be performed simultaneously, similar to the aforementioned learning tool T1.

[0143] In step SB5, the inspection condition setting unit **230** sets the output conditions for generating inspection results based on the judgment results. For example, when using the AI object detection tool T2 as the inspection tool to count the work W, it sets how many areas judged as objects by the AI object detection tool T2 will output the inspection result as "ON".

[0144] (During operation of the image inspection device) FIG. **6** is a flowchart showing the control procedure of the control unit **21** during inspection operation including the learning tool of the image inspection device S. The image inspection device S can switch between a setting mode for performing settings as shown in FIGS. **4** and **5**, and an operation mode shown in FIG. **6**, but this mode switching does not have to be clear, and for example, during operation in the operation mode, it is possible to temporarily switch to the setting mode to change settings and then return to the operation mode, allowing for continuous operation.

[0145] In step SC1 after the start, the imaging unit **1** captures the work W and acquires the captured image I1 of the work W. In step SC2, the inspection execution unit **400** starts inspection based on the configured learning tool for the image of the work W acquired in step SC1. First, in step SC3, based on the inspection range set by the inspection window setting unit **221**, the range to be inspected is cut out from the image of the work W acquired in step SC1.

[0146] In step SC4, the feature quantity of the image data of the inspection area cut out in step SC3 is extracted by the feature extraction unit **510**. In step SC5, the feature quantity extracted in step SC4 is judged by the judgment unit **520**. As mentioned above, in steps SC4 and SC5, the feature quantity changes depending on the learning tool or the classifier being executed.

[0147] In step SC6, the judgment result is generated by the learning tool. If inspection conditions related to the judgment result are set in the learning tool, the judgment result is determined based on the comparison result with the corresponding inspection conditions. For example, if the condition "is within ±15° angle with respect to the work W in the master image" is set for the AI object detection tool T2, the judgment result is generated based on this condition. In step SC7, the presence or absence of unprocessed configured inspection tools is determined. If there are unprocessed configured inspection tools, the process proceeds to step SC3, while if there are no unprocessed configured inspection tools, the process proceeds to step SC8. In step SC8, the inspection based on the configured inspection tools is concluded.

[0148] In step SC9, the inspection result output unit **410** outputs the inspection result. If there is only one inspection tool included in the inspection, the judgment result related to that inspection tool is output as the inspection result as is. However, when combining the judgment results of multiple inspection tools, the inspection result is generated and output based on the judgment results of each inspection tool.

[0149] (AI-OCR Details) FIG. **7** is a diagram showing the concept of the feature extraction unit **510** and the judgment unit **520** related to the classification of character type classes when the learning tool execution unit **403** executes the AI-OCR tool T3. In the execution of the AI-OCR tool T3, the learning tool execution unit **403** executes the character type output unit **523** for the classification of character type classes. Furthermore, the learning tool execution unit **403** executes the character type feature extraction unit **510***a* as the feature extraction unit **510** that extracts feature quantity F7 for the output of the character type output unit **523**. During the operation of the image inspection device S, when the image data of the captured image I1 containing characters is obtained by the imaging unit **1**, the image data is input to the pre-trained feature extraction unit **510**. The character type feature extraction unit **510***a* is a computational model with a network structure, which is a convolutional neural network trained by machine learning methods to extract feature quantity F7 suitable for the output of the character type output unit **523**. The feature quantity F7 is input to the character type output unit **523** for the recognition of characters in the image area, which is a part of the input image data, and classifies the image area into the existing character type (first character type) class. At this time, the learning tool execution unit **403** controls the computation processing by the pre-trained character type output unit **523**. Specifically, the learning tool execution unit **403** controls the classification task into the existing character type class by the pre-trained character type output unit **523**. Since the position where the characters are printed is sometimes emphasized in image inspection, the image area **500***a* where the AI-OCR tool T3 is executed is set in advance, and the feature quantity F7 for that image area **500***a* may be input to the character type output unit **523**.

[0150] The existing character type classes are multiple, and for example, character types such as alphabet, numbers, katakana, and hiragana are included in the existing character type classes. Characters may include symbols, and in this case, symbols are also included in the existing character type classes. The storage device **26** stores representative feature quantities of character type classes that represent feature quantities of character images belonging to the existing character type classes. The representative feature quantities of character type classes stored in the storage device **26** are accessible when performing character recognition processing.

[0151] The character type output unit **523** is a linear classifier that reads out the representative feature quantity of the character type class representing the character type class feature quantity of character images belonging to the existing character type class from the storage device **26**. Based on the character type class feature quantity extracted from one character image area at any position in the input image data

and the representative feature quantity of the character type class, it can output a value indicating the character type of the image area corresponding to the character type class feature quantity. Thus, for example, when the character type output unit **523** determines that the character type class feature quantity belongs to a specified character type class corresponding to a combination of character type and specified size, it can output the size of the character image in the image area based on the specified size included in the specified character type class. Note that when a character image combining multiple characters is registered as one character type class, the feature quantity F**7** input to the character type output unit **523** is treated as a feature quantity corresponding to one character image area.

[0152] In this embodiment, the size of the character image area is estimated by executing the

[0153] AI-OCR tool T**3**, and character recognition results corresponding to the size are output. Therefore, the learning tool execution unit **403** executes a size output unit **524** that outputs the size of the image area as the judgment unit **520**, and a size feature quantity extraction unit **510***c* that extracts feature quantity F**8** suitable for the output of the size output unit **524**. The size feature quantity extraction unit **510***c* is a convolutional neural network that has been pre-trained to extract feature quantity F**8** suitable for the output of the size output unit **524**, and feature quantity F**8** is a feature map. The size output unit **524** estimates and outputs where and what size of image area exists in the captured image I**1** based on feature quantity F**8**. In the AI-OCR tool T**3**, the character recognition result is output by combining the output from the character type output unit **523** and the output from the size output unit **524**. According to this, the character recognition accuracy is improved. For example, in the example of FIG. **7**, the width of the character image area occupied by "I" is smaller compared to the width of the character image areas occupied by other characters. If there is no part that outputs the size of the character image area, the size of the character image area is fixed, and character recognition is performed. If the size is fixed in the area of character images other than "I", adjacent other characters will enter the character image area of "I", resulting in a decrease in character recognition accuracy. By outputting the size of the character image area by the size output unit **524**, the character type output unit **523** can output character types assuming various sizes of image areas, thereby improving character recognition accuracy.

[0154] In the example shown in FIG. **7**, the learning of the feature extraction unit **510** is executed by the provider of the image inspection device S, and the configuration does not allow for on-site learning by the user. Regarding the character type output unit **523**, the user is enabled to perform on-site learning. That is, the parameters of the feature extraction unit **510**, which includes computationally intensive convolution operations, are fixed, and only additional learning of the character type output unit **523** is possible, allowing for additional learning by the CPU mounted in the control unit **21** without the need for a high-performance processing device such as a GPU. Furthermore, the size output unit **524** is also a part obtained by machine learning methods provided by the provider of the image inspection device S, that is, a part provided by pre-training, but since computationally intensive processing is required for further learning, the configuration does not allow for on-site learning.

[0155] Moreover, during inference, the inference by the feature extraction unit **510** is processed by, for example, the accelerator **21***c* specialized for convolution operations, and the inference by the judgment unit **520**, such as the character type output unit **523**, can be processed by, for example, DSP **21***a* or accelerator **21***c*.

[0156] The concept of pre-training of the character type output unit **523** will be explained based on FIG. **8**. This is also referred to as distance learning. The circle E**1** in FIG. **8** schematically represents the feature space, which is actually a multidimensional space. For example, when learning the character types "A" and "B", the same character type is learned so that the feature vectors approach each other, while the feature vectors of different character types are learned to move away from each other.

[0157] FIG. **9** shows the state of the character type output unit **523** when the image inspection device S is provided from the business operator to the user, that is, the state in which pre-learning of character types "A", "B", and "C" has been completed. As shown in this figure, basic alphanumeric characters have been pre-learned to be classifiable, and the representative vector, which is a representative feature vector, has been registered.

[0158] After the image inspection device S is provided to the user from the manufacturer, as shown in FIG. **10**, when the character "B" is read by the image inspection device S, it is read as "B." To explain in more detail, first, since "β" and "B" have different forms, the feature vector extracted from the character image of "β" is positioned away from the representative vector of the character type class "B." However, since the representative vector located in the vicinity of the feature vector of "β" is the representative vector of the character type class "B," the feature vector of the character image "β" is classified into the character type class "B."

[0159] When the character image "β" is read as "B", the user may want the character image "β" to be read as "β". In other words, since the character image "β" is similar in form to the already registered "B" in the existing character type class, it is read as "B" as shown in FIG. **10**, and such a reading result is output by the inspection result output unit **410**. The user, after confirming the inspection result, specifies the character image "β" as the learning image I**3** in the additional learning image designation unit **415** and instructs the on-site learning of the character type output unit **523**.

[0160] Specifically, the learning data generation unit **310***b* generates learning data D**1** that includes image area data containing "β" and specified character type information that specifies the character type indicated by the image area data containing "β". In this case, since the character type is "B", the specified character type information is information that specifies "β".

[0161] The class addition unit **315***b* of the judgment unit update section **315** adjusts the parameters of the character type output unit **523** to classify the image area of the learning image data possessed by the learning data D**1** generated by the learning data generation unit **310***b* into the class "β", which corresponds to the specified character type, that is, an additional character type class different from the existing character type class. More specifically, the representative vector of "β" is added to the representative vectors read during the execution of the character type output unit **523**, and the character type output unit **523** is adjusted to classify the image area corresponding to the feature vector determined to be close to the representative vector of "β"

included in the feature F7 as character type "β". At this time, the class addition unit **315***b* registers the representative vector of "β" based on the arrangement of the feature vector of "β" so that the feature F3 extracted from the character image "β", that is, the feature vector of "β" arranged in the feature space by the character type output unit **523** before the update, is not classified into the existing character type class "B". At this time, since the feature vector of "B" is also registered, when a character image closer to "B" than "β" is input, the feature F7 extracted from the character image is maintained in a position closer to the representative vector "B", resulting in being read as "B".

[0162] In this way, it is not necessary to adjust the arrangement of predetermined feature quantities in a multidimensional space, and it is sufficient to store the feature vector based on the feature vector of the image data specified additionally. Therefore, retraining equivalent to pre-training is not required, and the image inspection device S can perform on-site learning so that new character type class classification can be possible on the user side without deteriorating the reading performance at the time the device is provided from the business operator to the user. Furthermore, the learning image for on-site learning may be just one image.

[0163] (Example of Character Recognition) FIG. **11** specifically illustrates the flow of character recognition processing. First, during the operation of the image inspection device S, the image data of the captured image I1 obtained by the imaging unit **1** is input to the feature extraction unit **510**. The feature extraction unit **510** is a pre-trained part that has been pre-learned to extract features according to the application. The feature extraction unit **510** includes a character type feature extraction unit **510***a*, an object feature extraction unit **510***b*, and a size feature extraction unit **510***c*. The object feature extraction unit **510***b* extracts a feature F6 that indicates the object-like quality of the image area, that is, whether the image area is foreground or background. In addition, the size feature extraction unit **510***c* extracts a feature F8 related to the size of the image area. In this embodiment, for convenience, each feature extraction unit is described as a separate part, but it may also be configured such that each feature extraction unit extracts individual features from the features extracted by a common model structure. Furthermore, it may also be configured such that the same features are extracted for different applications.

[0164] The three features extracted by the feature extraction unit **510** are sent to the judgment unit **520** as the feature output unit.

[0165] The feature quantity F6 extracted from the target object feature extraction unit **510***b* is a feature map and is sent to the candidate region output unit **522***a* as an image region classification unit. The candidate region output unit **522***a* calculates the probability value that the image region corresponding to each convolution pixel is the target object based on the feature quantity F6. The probability value is calculated by known methods, such as calculating the similarity with the feature quantity indicating the image region of the target object. Then, the candidate region output unit **522***a* designates the image region where the probability value is above the threshold as a candidate region and outputs the candidate region information Dx,y indicating the position of the candidate region in the captured image I1. Note that the candidate region information does not include information related to the size of the candidate region. In this embodiment, in order to detect all character image regions that may be detected separately as adjacent character image regions or multiple character image regions in the captured image I1, the candidate region information Dx,y is output without considering the spatial information in the captured image I1. However, it may also be configured to generate a heat map in which the character likelihood is arranged according to the spatial information of the captured image I1 and to output the candidate region information based on the peak position in the heat map. With this configuration, it is possible to reduce overlapping candidate regions for the same character image region, thereby reducing the computational cost of processing using candidate region information. When outputting candidate region information Dx,y without considering spatial information in captured images **11**, for example, it can prevent omission of output for correct character regions near peak positions that differ from peak positions, thus improving OCR accuracy.

[0166] The feature quantity F7 extracted by the character type feature quantity extraction unit **510***a* is sent to the character type output unit **523**. The feature quantity F7 is a feature map, and this feature map has H dimensions (height) and C dimensions (feature quantity). The character type output unit **523** outputs a value indicating the character type of the corresponding image area based on the feature quantity corresponding to the image area indicated by the candidate region information Dxy. More specifically, based on the candidate region information Dxy, the feature quantity f71 corresponding to the first candidate region P1 is identified from the feature quantity F7, and the character type is output based on the feature quantity f71. Here, the character type feature quantity may be normalized to a length of 1. It is also possible that the feature quantities F6 and F7 are common feature quantities, which reduces the processing of the feature quantity extraction unit **510**. In this embodiment, the configuration identifies the feature quantity f71 from the feature quantity F7, but it may also be a configuration in which only the feature quantities of the candidate regions are extracted from the feature quantity extraction unit **510** based on the candidate region information Dxy. Furthermore, in this embodiment, the character type output unit **523** identifies the feature quantity f71 based on the candidate region information Dxy to speed up the processing of the character type output unit **523**, but it may also be a configuration that outputs the character type for all or part of the convolution pixels of the feature quantity F7 as a feature map.

[0167] The character type output unit **523** infers which character type class the candidate region P1 corresponding to the feature quantity f71 belongs to by calculating the product of the dictionary matrix DM, as shown in FIG. **11**, and the feature quantity f71 as a feature vector. The dictionary matrix DM contains representative vectors for each character type class corresponding to the number of registered characters (the number of character type classes). The character type output unit **523** outputs the probability values that the candidate region P1 belongs to each character type class as scores by calculating the product of the feature quantity f71 and the dictionary matrix DM. In this way, the character type output unit **523** calculates scores for each character type class for each candidate region specified by the candidate region information Dxy. Therefore, the information output by the character type output unit **523** is a combination of the candidate region information Dxy and the character type information Dcl related to the character

types of each candidate region. The character type information Dcl is composed of scores related to all character type classes indicated by the dictionary matrix DM, but it may also be information regarding only some character type classes, such as those with high scores, or information that does not include scores.

[0168] The feature quantity F**8** extracted by the size feature quantity extraction unit **510***c* is sent to the size output unit **524**. The size output unit **524**, as the judgment unit **520**, outputs size information Dhw related to the size (width, height) of the image area based on the feature quantity F**8**. Since the feature quantity F**8** is a feature map, the size output unit **320***f* can output the size information Dhw of the character image of each image area based on the feature quantities of each convolution pixel constituting the feature quantity F**8**, and outputs a combination of the position of the image area contained in the captured image I**1** and the size information Dhw of the image area. For example, when the image area is determined not to belong to the specified character type class corresponding to the combination of the character type and the specified size described later, based on the feature quantity F**7** extracted by the character type feature quantity extraction unit **510***a*, the character type output unit **523** is configured to output the size information Dhw of the image area, namely the character image area. Note that the feature map as the feature quantity F**8** is extracted without considering whether it is a character image area or not, so the convolution pixels that are not character image areas contain values themselves. In this embodiment, the size information is expressed in terms of width and height, but it may also be expressed in terms of the subpixel position relative to the pixel that specifies the position of the image area.

[0169] The duplicate judgment unit **526** acquires the candidate region information Dxy output by the character type output unit **320***b* and the character type information Dcl, as well as the size information Dhw for each image area, and determines the duplication of the candidate region based on the character type class and size when the candidate region is a character image area.

[0170] The character type class of the candidate region is not considered in the process of outputting candidate region information Dxy from the captured image I**1**. Therefore, there is a possibility that multiple candidate regions are output from the same character image area. For this reason, when multiple adjacent candidate regions are determined to be of the same character type class, it is preferable to determine one of the candidate regions as a duplicate candidate region and delete it. However, when the candidate regions are correctly determined from the adjacent captured image I**1** of the same character type, multiple adjacent candidate regions are also determined to be of the same character type class, so it is preferable to consider the spatial overlap of each candidate region in the captured image I**1**. Therefore, the duplicate determination unit **526** deletes duplicate candidate regions based on candidate region information Dxy, character type information Dcl, and size information Dhw. As will be described in detail later, when the image area is determined to belong to a specified character type class corresponding to a combination of character type and specified size based on feature F**7**, the size of the candidate region in the captured image I**1** is specified by candidate region information Dxy and character type information Dcl, so the spatial overlap in the captured image I**1** does not necessarily have to be determined based on size information Dhw. As a specific processing method, known methods such as Non-Maximum Suppression can be used. The duplicate determination unit **526** deletes candidate regions according to the determination result and outputs the character reading result R**1** of the captured image I**1** based on the remaining candidate regions.

[0171] By going through the flow of the above processing, the judgment unit **520** as the feature output unit outputs the reading result, and the user can obtain a reading result that includes a reading result display in which a rectangular GUI based on the output result from the size output unit **320***f* is superimposed, and character type information based on the output result from the character type output unit **320***b* is displayed adjacent to the rectangular GUI.

[0172] In this embodiment, overlapping candidate regions are deleted based on candidate region information Dxy, character type information Dcl, and size information Dhw. However, candidate regions may also be deleted based on either candidate region information Dxy and character type information Dcl, or solely on candidate region information Dxy. In this case, as mentioned above, there is a risk that the accuracy of duplicate determination may decrease, but the computational processing (in this embodiment, processing by character type output unit **523**) that increases with the number of candidate regions can be reduced. The same applies when duplicate determination is based on candidate region information Dxy and size information Dhw.

[0173] (Details of Dictionary Registration) FIG. **12** is a diagram showing a specific example of the dictionary registration process. The dictionary registration process is on-site learning of the AI-OCR tool T**3**, which includes updating the character type output unit **523** by the class addition unit **315***b*. For example, the case where a user registers the character "B" in the dictionary will be explained. The image data of the captured image I**1**, which includes the character "B", is acquired by the imaging unit **1**, and the user selects the captured image I**1** as the learning image I**3** using the learning image selection unit **310***a*.

[0174] FIG. **13** is a diagram showing the GUI **540** generated by the learning data setting unit **310**. The user sets label information for the learning image I**3** using the label information setting unit **310***c*. When registering in the dictionary, the label information setting unit **310***c* generates a specification reception GUI **540** for accepting the user's specification of character position, character size, and label, and displays it on the display device **4**. This specification reception GUI **540** has a target image display area **541** that displays the learning image I**3** and a label information display area **542** that displays the label information set for the learning image I**3**. In the target image display area **541**, a rectangular box **544** whose shape changes according to the user's operation is superimposed. In the label information display area **542**, the specified character type, specified position, and specified size are displayed for each box **544**. When the user sets label information for the learning image I**3** using the label information setting unit **310***c*, the user first operates the position and size of the box **544** to correspond to the character image area of the learning image I**3** displayed in the target image display area **541**. When the user operates the box **544**, the values of the specified position and specified size in the label information display area **542** change according to the operation content. The label information display area **542** also functions as an area that

accepts user input, and the user performs input operations for the character type corresponding to the character area in the specified character type of the label information display area **542**. When a character type is input into the label information display area **542**, the input character type is displayed in the character type input region **543** near to the corresponding box **544** in the target image display area **541**. The user can add or delete boxes **544** according to the number of character areas on the image **500**, and the label information display area **542** is provided with a display area corresponding to the number of boxes **544**. In addition, the area where the specified position and the specified size are displayed in the label information display area **542** also functions as an input area. As the specified position, the x-coordinate and y-coordinate for specifying the position of the character can be input, and as the specified size, the width and height for specifying the character size can be input. Furthermore, the character type input operation may be performed on the character type input region **543** superimposed on the target image display area **541**.

[0175] In the example of FIG. **13**, the GUI **540** for the case where the user adds two "β" with different fonts for on-site learning is shown. The two "β" in the learning image I**3** look different because the fonts are different. The user places two boxes **544** for the two character image areas "β" and specifies the position and size of the corresponding character image area "β". For convenience, the box **544** assigned the number 1 in FIG. **13** is referred to as box **544***a*, and the box **544** assigned the number 2 is referred to as box **544***b*. In the label information display area **542**, the position and size of the corresponding character image areas are displayed according to boxes **544***a* and **544***b*, and as shown in the label information display area **542**, the two "β" also differ in size. These two character image areas have the same character type "β", but when the two character image areas are additionally subjected to on-site learning, the dictionary matrix DM will include feature vectors representing the "β" specified by box **544***a* in GUI **540** and the feature vectors representing the "β" specified by box **544***b* as separate classes. In this way, the learning data generation unit **310***b* generates learning data D**1** that has specified size information indicating the size of the character image area in the image data of the learning image I**3**. The generated learning data D**1** is input to the classifier update unit **315**. In the classifier update unit **315**, as the feature extraction unit **510**, the character type feature extraction unit **510***a* is executed to extract feature F**7** from the learning image I**3**, and the object feature extraction unit **510***b* is executed to extract feature F**6** from the learning image I**3**.

[0176] Returning to FIG. **12**, the details of the processing by the classifier update unit **315** will be explained. The class addition unit **315***b* as the classifier update unit **315** executes the character type feature extraction unit **510***a* to extract the feature F**7** and identifies the feature F**3** corresponding to the character image area specified by the user based on the specified position information (the x-coordinate and y-coordinate specified by the user) included in the learning data D**1**. In this embodiment, the learning image I**3** included in the learning data D**1** specifies two character image areas by boxes **544***a* and **544***b*, so two feature vectors are identified, and the class addition unit **315***b* adds the identified two feature vectors directly to the dictionary matrix DM. The boxes **544***a* and **544***b* are character image areas of the same character type, but are registered as feature vectors corresponding to different classes. In this embodiment, the identified features are added directly to the dictionary matrix DM, but it is also acceptable for features that can be sufficiently distinguished from existing representative features to be selected and added to the dictionary matrix DM based on the features.

[0177] The classification unit update part **315***a* as the classifier update unit **315** executes the object feature quantity extraction unit **510***b* to extract feature quantity F**6** as a feature map, and extracts feature quantity F**10** corresponding to the image area specified by the user based on the specified position information included in the learning data D**1**. The image area specified by the specified position information is the image area designated by the user as the character image area, so feature quantity F**10** corresponds to the image area treated as a foreground area rather than a background. Therefore, the score, which is the probability value that the image area corresponding to feature quantity F**10** is the object area, is updated in the candidate region output unit **522***a* so that it becomes higher than the score when the candidate region output unit **522***a* determines the candidate region. The method of updating the candidate region output unit **522***a* is not particularly limited, and for example, if a configuration is introduced that incorporates learning by SVM or evaluation by cosine similarity in the updated foreground output unit **320***c*, it can be learned by known methods.

[0178] While the learning tool execution unit **403** executes the size feature extraction unit **510***c*, the classifier update unit **315** does not execute the size feature extraction unit **510***c* in the dictionary registration process. Generally, a model that infers the size of a predetermined image area included in the input image data becomes computationally intensive when attempting to update it using machine learning methods. That is, when trying to update the size output unit **524** using machine learning methods so that size information Dhw based on specified size information is output for the image area of the learning data D**1**, the learning load becomes so large that it is difficult as on-site learning. Therefore, in the on-site learning of this embodiment, the update of the size output unit **524** is not performed, and thus, the size feature extraction unit **510***c* is not executed.

[0179] Therefore, in the on-site learning of this embodiment, the specified size information of the learning data D**1**, that is, the width and height specified by the user via the specification acceptance GUI **540**, is reflected in the dictionary matrix DM and applied during inference after the dictionary registration process. More specifically, the additional character type class feature quantity is registered in the dictionary matrix DM as a feature corresponding to the combination of the character type and the size of the image area. The character image "β" specified in box **544***a* and the character image "β" specified in box **544***b* have the same character type "β" but different sizes, so the feature vector identified by box **544***a* corresponds to the combination of character type "β" and the size specified by box **544***a*, and the feature vector identified by box **544***b* corresponds to the combination of character type "β" and the size specified by box **544***b*, and is registered in the dictionary matrix DM. When the learning tool execution unit **403** executes the character type output unit **523**, if the feature quantity f**71** is determined to belong to the additional character type class, the candidate region P**1** is determined to be an image area

having the character image of the character type specified by the learning data D**1** and the size specified by the learning data D**1**. In the example of FIG. **12**, two character type classes with the character type "β" are added, and if the candidate region P**1** is determined to belong to either of the two added character type classes, then it is determined that candidate region P**1** has a character type of "β", and its size reflects that of box **544** used for identifying features.

[0180] The update of the character type output unit **523** by the class addition unit **315***b* is performed not only to add character types other than those that can be classified by pre-training, but also when adding character image areas that were not read from existing character types. If there is an imaging image I**1** for which reading has failed in the inspection results output by the inspection execution unit **400**, the imaging image I**1** is used as a learning image I**3**, and by performing on-site learning, the accuracy of the character type output unit **523** is improved.

[0181] At this time, as a representative example of the captured image I**1** that fails to read, there is a captured image I**1** that includes a blurred character image area. In this case, if the learning tool execution unit **403** executes the candidate region output unit **522***a* separately from the character type output unit **523** during the execution of the AI-OCR tool T**3**, it can reduce the decrease in reading accuracy due to on-site learning. More specifically, the blurred character image area may be close to the feature quantity of the background image area. In this case, if the feature vector corresponding to the blurred character image area is added to the dictionary matrix DM, the character type output unit may classify the background image area into the class corresponding to the blurred character image area, leading to a risk of misdetection. In this embodiment, the candidate region output unit **522***a* is executed separately from the character type output unit **523**, and based on the output from the candidate region output unit **522***a,* the processing of the character type output unit **523** is executed, thereby reducing the risk of misdetection.

[0182] (Relearning after Operation) The image inspection device S is a device capable of executing a pre-trained character recognition model, as mentioned above. After the operation of the image inspection device S (also referred to as after operation), there may be misreading by the character recognition model; however, the image inspection device S of this embodiment extracts an image area, which is a part of the image in the input image data, when classifying a certain character, allowing user instruction regarding the misreading result to be possible using that image area. Furthermore, the image inspection device S can accept user instruction regarding the misreading result, and by accepting user instruction regarding the misreading result, it becomes possible to execute a model that requires a small amount of computation for learning based on user instruction. Additionally, since the image area is extracted, the user can provide instruction without setting the image area.

[0183] After the operation of the image inspection device S, the process for enabling the re-learning of the pre-trained model will be explained based on the flowchart shown in FIG. **14**. This flowchart starts after the specification of the learning image is made by the additional learning image designation unit **415**. In step SD**1**, the control unit **21** acquires the operation result of the image inspection device S and displays it on the display device **4**. This step can be referred to as the operation result display step or the step of presenting the operation result to the user. FIG. **15** shows an example of a GUI for displaying the operation result, which is the operation result display screen **600**. The operation result display screen **600** can be generated by the control unit **21** and displayed on the display device **4**.

[0184] The operation result display screen **600** is provided with an operation result display area **601** and an operation reception area **602**. The operation reception area **602** is equipped with a reading setting button **602***a* for setting the reading, a character learning button **602***b* for starting character learning, a judgment condition button **602***c* for setting judgment conditions, a button **602***d* for performing test operation/character learning, and a learning content list button **602***e* for displaying a list of learning contents. Each button **602***a,* **602***b,* **602***c,* **602***d,* and **602***e* is composed of an image displayed on the display device **4**, allowing touch operations using the touch panel **4***a;* however, it may also be composed of physically operating buttons. The same applies to the buttons below.

[0185] The operation result display area **601** displays the image input to the model. In this example, "100 kΩ" is the string that the model wants to read. In the operation result display area **601**, a first box **601***a* that surrounds the image area containing the string to be read and a second box **601***b* that surrounds the area of the characters read by the model are superimposed, and the reading results from the model, "1", "0", and "0" are also superimposed. The operation result display screen **600** allows the user to grasp the reading results.

[0186] In the example shown in FIG. **15**, "k" and "Ω" are misread. "k" is a character that is pre-registered in the image inspection device S, but it is a character that has been misread. "Ω" is a character that is not pre-registered in the image inspection device S, and therefore it is a character that has been misread. In other words, "k" and "Ω" are both misread characters, but they differ in whether they are characters pre-registered in the image inspection device S or not.

[0187] After the operation result display step of step SD**1** in FIG. **14**, proceed to step SD**2**, where the control unit **21** accepts the designation of the character image area by the user. Specifically, when the user operates the character learning button **602***b* shown in FIG. **15**, the control unit **21** displays the additional learning window **610** shown in FIG. **16** in the operation reception area **602** of the operation result display screen **600**. The additional learning window **610** is provided with an add button **610***a* for adding characters to be learned and a learning start button **610***b* for starting the learning.

[0188] When the user operates the add button **610***a,* the control unit **21** displays the additional learning window **620** shown in FIG. **17** in the operation reception area **602** of the operation result display screen **600**. In the additional learning window **620**, reading settings are enabled. This example shows the case of adding the character "k" for additional learning, and when performing the reading settings, first, the user forms a third box **601***c* that surrounds the character "k" to be learned on the image displayed in the operation result display area **601**. The third box **601***c* can be formed by touch operations by the user, for example, by dragging from the upper left to the lower right of the character to be learned to form the third box **601***c*. Once the third box **601***c* is formed, the control unit **21** identifies the character image area

surrounded by the third box **601***c* and accepts the designation of the character image area.

[0189] Then, the process proceeds to step SD**3** shown in FIG. **14**, where the control unit **21** accepts the specification of the character type of the characters included in the character image area received in step SD**2**. The additional learning window **620** shown in FIG. **17** allows for the setting of whether or not the characters enclosed in the third box **601***c* are to be the learning target. Specifically, the additional learning window **620** is provided with a character setting area **620***a* for setting the characters enclosed in the third box **601***c* as the correct characters, and a reading exclusion setting area **620***b* for setting the characters enclosed in the third box **601***c* as characters excluded from reading.

[0190] When the setting button **620***c* of the character setting area **620***a* is operated, the control unit **21** generates the character type selection window **630** shown in FIG. **18** and displays it on the display device **4**. The character type selection window **630** is provided with a character type display area **631** in which the character types (registered character types) that are pre-registered in the image inspection device S are listed. The character type display area **631** displays multiple tabs, allowing the user to select any tab. The multiple tabs include, for example, a tab classified for numbers/symbols, a tab classified for uppercase alphabet letters, a tab classified for lowercase alphabet letters, and a user dictionary tab that classifies characters registered by the user. When the user performs an operation to select the desired tab, the character types classified under the selected tab are listed in the character type display area **631**. The character types displayed in the character type display area **631** can each be selected by the user, and the example shown in FIG. **18** illustrates the case where the user selects 'k'.

[0191] The control unit **21** identifies the character type selected by the user, and as shown in FIG. **19**, displays the character type selected by the user in the character setting area **620***a*. This allows the user to confirm the character type they have selected.

[0192] FIG. **20** shows an example of accepting the designation of a character type that is not registered in the image inspection device S, that is, an unregistered character type. If "Ω" is an unregistered character type in the image inspection device S, first, the user forms a fourth box **601***d* surrounding the character "Ω" that they want to learn on the image displayed in the operation result display area **601**. The fourth box **601***d* can be formed in the same manner as the third box **601***c*.

[0193] After the formation of the fourth box **601***d*, when the user operates the setting button **620***c* of the character setting area **620***a*, the control unit **21** generates and displays the character type selection window **630** shown in FIG. **21** on the display device **4**. This example shows the case where no character types are registered in the user dictionary, and a new registration button **631***a* for newly registering character types is displayed.

[0194] When the new registration button **631***a* is operated, the control unit **21** displays the new registration window **640** shown in FIG. **22**. In the new registration window **640**, only one character is accepted for input. However, if you want to input only one character from multiple characters that make up an idiom, you can first accept the input of the idiom and then allow the operation of deleting unnecessary characters to leave only the necessary character. This makes the character input operation easier. FIG. **23** shows the state where the input of "Ω" is completed.

[0195] After receiving the specification of the character type as described above, the process proceeds to step SD**4** shown in FIG. **14**.

In step SD**4**, the control unit **21** receives the learning execution instruction from the user, but before receiving the learning execution instruction, the character types received in steps SD**2** and SD**3** are displayed in the character type display area **612** of the additional learning window **610** shown in FIG. **24**. When the user operates the learning start button **610***b*, the process advances to step SD**5** in FIG. **14**, where the control unit **21** executes the additional learning of the model.

[0196] After step SD**5**, a test operation can be performed to evaluate the effect of additional learning. The control unit **21**, upon receiving instructions for the test operation from the user, executes the process in which the character recognition model after additional learning classifies the input image area into character type classes. FIG. **25** shows an example of a result display screen **650** that displays the results of the test operation. This example indicates that the characters "k" and "Ω" that underwent additional learning have been classified. If there are misreadings during the test operation, the user can confirm this on the result display screen **650**, allowing for corrections to be made at this stage for steps SD**2** and SD**3** in FIG. **14**.

[0197] (Template Specification) FIG. **26** is a diagram showing an example of an operation screen **700** displayed during operation when inspecting the date printed or otherwise affixed to the work W. The operation screen **700** is a screen generated by the control unit **21** and displayed on the display device **4**, and it is provided with an image display area **701** where the image input to the model is displayed and an additional learning button **702** for operating when performing additional learning. In the example shown in FIG. **26**, the date is registered as a master. The image display area **701** is configured to display the master date and time and the reading date and time read by the model.

[0198] Here, for example, we assume a case where a workpiece W with a printed manufacturing date is inspected. If "Jan. 1, 2024" is registered as the master in the image inspection device S, the workpiece W manufactured on "Jan. 1, 2024" will be the inspection target. However, the workpiece W manufactured the next day will have "Jan. 2, 2024" printed on it, so if the master remains as "Jan. 1, 2024", all workpieces W that are originally not problematic will be judged as "defective". Therefore, the user needs to change the setting of the master date every day before operation, which is a significant burden. The same applies to expiration dates that change in relation to the manufacturing date.

[0199] In this embodiment, a template specification function is equipped. In the template specification function, for example, when the user specifies the format of the date, the image inspection device S automatically executes the date setting change using the current date and time information held internally. The specific setting method when using the template specification function will be explained below.

[0200] First, the control unit **21** generates a selection window **710** (shown in FIG. **27**) that accepts the selection of the OCR mode and displays it on the display device **4**. The selection window **710** is provided with a character string button **710***a* for selecting a character string mode suitable for reading fixed character strings (unchanging character

strings), a date/time button **710***b* for selecting a date/time mode suitable for reading changing character strings such as dates and times, and a custom button **710***c* that allows customization of judgment conditions according to the printed content of the work W.

[0201] When the date/time button **710***b* is operated by the user, the control unit **21** generates the tool setting screen **720** as shown in FIG. **28** and displays it on the display device **4**, and also generates the editing window **722** and displays it on the display device **4**. The tool setting screen **720** is provided with an image display area **721** where the image input to the model is displayed. The editing window **722** displays options such as year/month/day, day/month/year, month/day/year, month/year, hour/minute, hour, and minute, and the user selects an option that matches the inspection target from these options.

[0202] FIG. **29** shows a case where the user selects the year, month, and day. In this case, the control unit **21** generates and displays a judgment condition setting window **730** on the display device **4** for setting judgment conditions. The judgment condition setting window **730** is provided with a master date and time input area **731** for inputting the master date and time, and a synchronization setting area **732** for setting calendar synchronization. The date and time entered in the master date and time input area **731** is registered as the master. In the synchronization setting area **732**, one can select between a synchronization mode that automatically executes date setting changes using the date and time information inside the image inspection device S, and an asynchronous mode that does not synchronize with the date and time information inside the image inspection device S. Changing the master date and time using the date and time information inside the image inspection device S is referred to as calendar synchronization. When the synchronization mode is selected, the control unit **21** acquires the date and time information inside the image inspection device S, and if the acquired date is determined to be the next day, the master date and time is automatically changed to the next day. The same applies to the time, where the control unit **21** acquires the time information inside the image inspection device S and automatically changes it to be the master time.

[0203] When the synchronization setting button **732***a* shown in FIG. **29** is operated, the control unit **21** generates the offset setting window **740** shown in FIG. **30** and displays it on the display device **4**. The offset setting window **740** is a window for accepting the setting of the offset amount when the user wants to offset the registered date and time as a master by a predetermined date and time. The offset setting window **740** is provided with a setting area **741** that allows the offset amount to be set in months, days, and minutes, an allowable error setting area **742** for setting the range that can be tolerated as an error, a calculation order setting area **743** for setting the calculation order of the offset, a one-month offset setting area **744**, a time display format setting area **745**, and a setting confirmation area **746**. With this offset setting window **740**, the user can easily set any offset amount. For example, as shown in the setting confirmation area **746**, if the manufacturing date is "Jan. 1, 2023," when offsetting by 12 months, it can be confirmed that the master is "Jan. 1, 2024." The set offset amount is reflected in the master by the control unit **21**.

[0204] (Custom Setting) The image inspection device S may be configured to allow custom settings by the user when template designation cannot be accommodated. FIG. **31** is a diagram explaining the case where the master string changes for each imaging, and among the images displayed in the operation result display area **601**, the "0001" in the bottom right is a count-up type master string that increases by one for each imaging, which is similar to a manufacturing number. In such a case of the master, the user operates the custom button **710***c* in the selection window **710** shown in FIG. **27**. Then, the control unit **21** generates and displays a judgment condition setting window **750** for setting the judgment conditions for custom settings, as shown in FIG. **32**, on the display device **4**. The judgment condition setting window **750** is provided with a setting button **751** for executing format settings. When the setting button **751** is operated, the control unit **21** generates and displays a format setting window **770** on the display device **4**, as shown in FIG. **33**. The format setting window **770** is provided with a separation setting area **771** for separating the master string by elements. In the example shown in FIG. **33**, the character string consists of eight elements: "best before date", "2024", ".", "01", ".", "01", "+K", and "0001". In this case, as shown in FIG. **34**, a separation is set between "best before date" and "2024", between "2024" and ".", between "." and "01", between "01" and ".", between "." and "01", between "01" and "+K", and between "+K" and "0001". When setting the separation, it is sufficient to perform an operation to select a mark indicating the separation.

[0205] After separating the master string into elements, the content can be specified for each element. After the separation is complete, as shown in FIG. **35**, the format setting window **770** displays the content setting area **772**. In the content setting area **772**, multiple elements are listed, and when the user performs an operation to select one element, the first selection window **772***a* shown in FIG. **36** or the second selection window **772***b* shown in FIG. **37** is displayed. The user can select the desired content from the multiple options shown in the first selection window **772***a* or the second selection window **772***b*. The selected content is reflected in the master. At this time, when synchronizing with the calendar, the offset setting window **740** shown in FIG. **30** is displayed on the display device **4**, allowing for the setting of the offset amount.

[0206] Moreover, when the element is a count-up type string or a count-down type string, the control unit **21** generates a count-up/down setting window **780** as shown in FIG. **38** and displays it on the display device **4**. The count-up/down setting window **780** is provided with a basic setting area **781**, a count-up/reset setting area **782**, and a digit number setting area **783**. In the basic setting area **781**, the start value, end value, addition/subtraction value, and serial number value can be set. In the count-up/reset setting area **782**, settings such as the trigger count can be made. In the digit number setting area **783**, it is possible to enable or disable zero padding and set the number of digits.

[0207] FIG. **39** shows the replacement settings window **790**. In this replacement settings window **790**, it is possible to link the display of the corresponding month for each country with the calendar. This allows for accommodating different languages and date formats depending on the country.

[0208] FIG. **40** shows a linking window **800** for linking the representations of early part of the month, middle part of the month, and latter part of the month with the calendar. In the linking window **800**, when setting to link the representations of early part of the month, middle part of the month,

and latter part of the month with the calendar, it is possible to input the same input items such as early part of the month, middle part of the month, and latter part of the month in bulk using a bulk input window **810** as shown in FIG. **41**.

(OCR circumference Search Function)

[0209] As shown in FIG. **42**, there are cases where multiple characters included in the image are arranged in an arc shape. In this embodiment, instead of setting one tool for each character, it is possible to specify the character image and input it into the model, so in the editing window **722**, by specifying "arc," it becomes possible to specify the string range **721***a* arranged in an arc shape. However, as shown in FIG. **43**, there are cases where an image with a changed phase of the string arranged in an arc shape is input. In general position correction tools, the center position of the circle can be positioned, but the positioning of the phase cannot be done, so the string to be detected may fall outside the string range **721***a*.

[0210] In response to this, the image inspection device S is capable of handling cases where the phase of the character string arranged in an arc shape changes, by using the OCR circumference search function. Specifically, as shown in FIG. **44**, the control unit **21** generates and displays an arc setting window **725** on the display device **4**. The arc setting window **725** is provided with a reading direction specification area **725***a* for specifying whether the reading direction is clockwise or counterclockwise, and a circumference search setting area **725***b* for setting whether to enable the circumference search function. When the circumference search is enabled in the circumference search setting area **725***b*, a circular search range **721***b* is displayed in the image display area **721**, separate from the character string range **721***a*.

[0211] FIG. **45** shows test images with different phases of character strings, and additional learning can be performed using such test images. As shown in FIG. **46**, even if images with different phases of character strings are input during the operation of the image inspection device S, inspection becomes possible.

[0212] FIG. **47** shows a case where a part of the character string arranged in an arc shape registered as a master is missing, resulting in a defective inspection result. In such cases of missing data, the model is configured to read out character strings that have a close edit distance.

[0213] FIG. **48** is an image showing an additional learning confirmation window **820** that confirms whether or not to perform additional learning with the image when an image with different phases of a character string arranged in an arc shape is input. The user can select OK to perform additional learning with the image displayed in the additional learning confirmation window **820**, or select Cancel if they do not wish to perform additional learning.

[0214] FIG. **49** is a diagram explaining the case where the third box **601***c*, which surrounds the characters to be learned during additional learning, is moved. When the user moves the third box **601***c*, the movement direction of the third box **601***c* is set so that it automatically moves along the circular search range **721***b*. This allows the third box **601***c* to be easily moved in the desired direction. When reading a string of characters arranged in an arc shape with the model, reading is executed after expanding it into a rectangular strip.

[0215] The aforementioned embodiments are merely illustrative in all respects and should not be interpreted restrictively. Furthermore, any modifications or changes that fall within the equivalent range of the patent claims are all within the scope of the present invention.

INDUSTRIAL APPLICABILITY

[0216] As described above, the image inspection device according to the present disclosure can be used for inspecting various works.

What is claimed is:

1. An image inspection device in which a pre-trained character recognition model is executed to classify an image area, which is a partial area in an input image data, into a first character type class, comprising:

a control unit configured to execute the pre-trained character recognition model and to function as a learning data generation unit configured to generate learning data and a learning execution unit configured to execute updating of the pre-trained character recognition model based on the learning data, wherein

the pre-trained character recognition model includes:

a feature extraction unit configured to extract a feature from the input image data, the feature indicating a characteristic of an image data, and

a character type output unit configured to output a character type based on the feature extracted by the feature extraction unit,

the learning data generation unit generates the learning data that includes learning image data, specified position information indicating a relative position of a character in an image of the learning image data, specified character type information indicating the character type of the character located at the relative position, and specified size information indicating a size of the character in the image,

the learning execution unit updates the pre-trained character recognition model so as to classify the feature, the feature being extracted in a case that the learning image data is input to the feature extraction unit and corresponding to the relative position indicated by the specified position information, into a specified character type class corresponding to a combination of the character type indicated by the specified character type information and the size indicated by the specified size information.

2. The image inspection device described in claim **1**, wherein:

the control unit includes a convolutional operation network inference accelerator configured to perform operations of a convolutional neural network as the feature extraction unit.

3. The image inspection device described in claim **1**, wherein:

the feature extraction unit includes;

a character type class feature extraction unit configured to extract the character type class feature, the character type class feature being the feature related to a character type class of the image area, and

a foreground-background feature extraction unit configured to extract a foreground feature indicating whether the image area is foreground or background,

the pre-trained character recognition model includes a foreground output unit configured to determine whether the image area is foreground based on the foreground feature; and

the character type output unit outputs a value indicating the character type of the image area corresponding to the image area determined as foreground by the foreground output unit.

4. The image inspection device described in claim **1**, wherein:

the feature extraction unit includes;

a character type class feature extraction unit configured to extract the character type class feature, the character type class feature being the feature related to a character type class of the image area, and

a size feature extraction unit configured to extract a size feature, the size feature being the feature related to the size of the image area; and

the character type output unit outputs the size of the image area based on the specified size information included in the specified character type class, when the character type class feature belongs to the specified character type class corresponding to the combination of the character type and the size.

5. The image inspection described in claim **4**, wherein:

the pre-trained character recognition model includes a size output unit configured to output the size of the image area based on the size feature; and

the size output unit outputs the size of the image area, when the character type class feature does not belong to the specified character type class corresponding to the combination of the character type and the size.

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