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(54) **DATA COLLECTION DEVICE AND DATA COLLECTION METHOD**

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G06V 10/74	(2022.01)
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(52) **U.S. Cl.**
CPC ***G06V 10/774*** (2022.01); ***G06V 10/761*** (2022.01); ***G06V 10/82*** (2022.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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(57) **ABSTRACT**

Provide a data collection device capable of reducing the burden on a user associated with generating training data for a data recognition model. A data collection device includes a first CNN, a second CNN, a comparison unit that compares a recognition result for input data by the first CNN to a recognition result for the input data by the second CNN, and a data collection unit that collects the input data as training data according to a comparison result of the comparison unit.

21 Claims, 8 Drawing Sheets

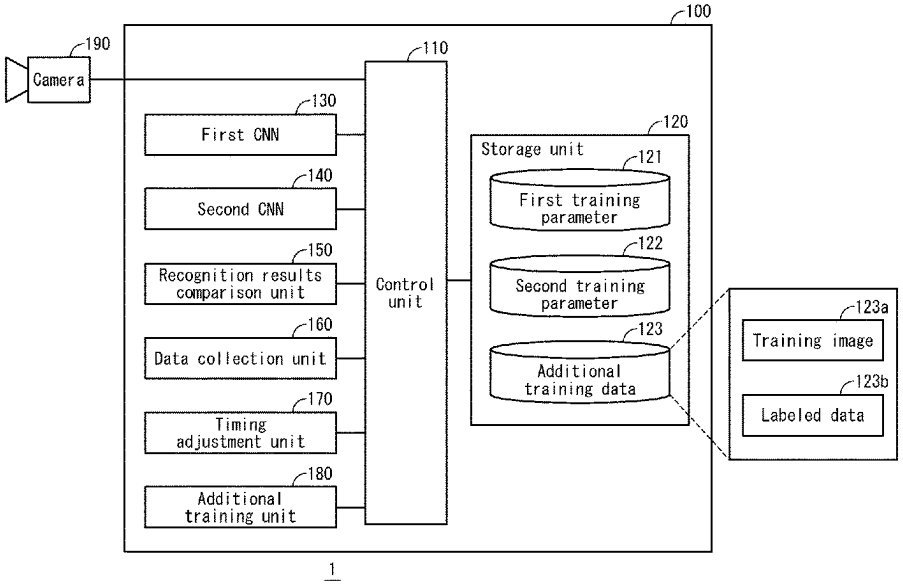

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FIG. 1

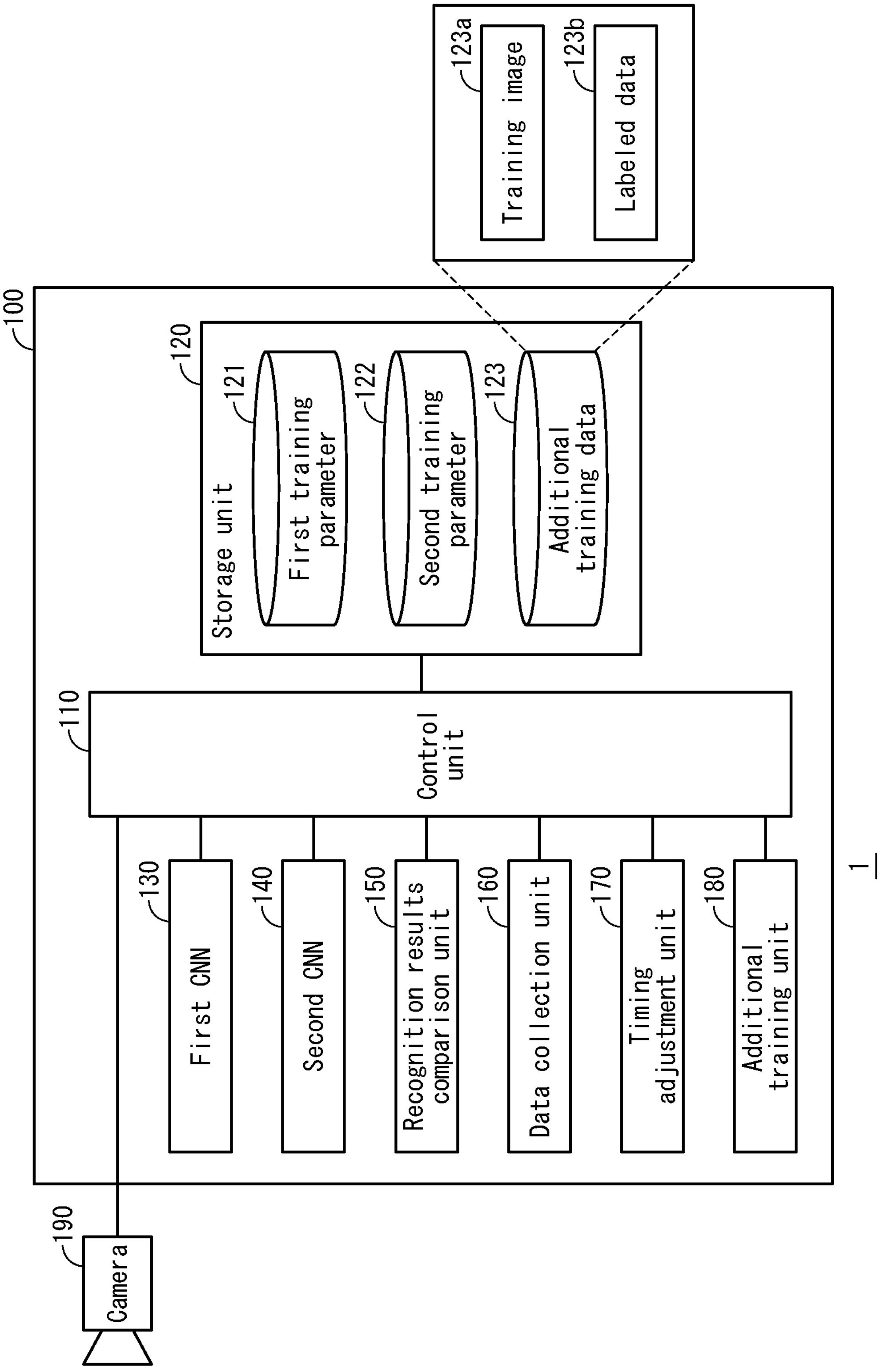

1
100
110
Control unit
120
Storage unit
121
First training parameter
122
Second training parameter
123
Additional training data
123a
Training image
123b
Labeled data
130
First CNN
140
Second CNN
150
Recognition results comparison unit
160
Data collection unit
170
Timing adjustment unit
180
Additional training unit
190
Camera

FIG. 2

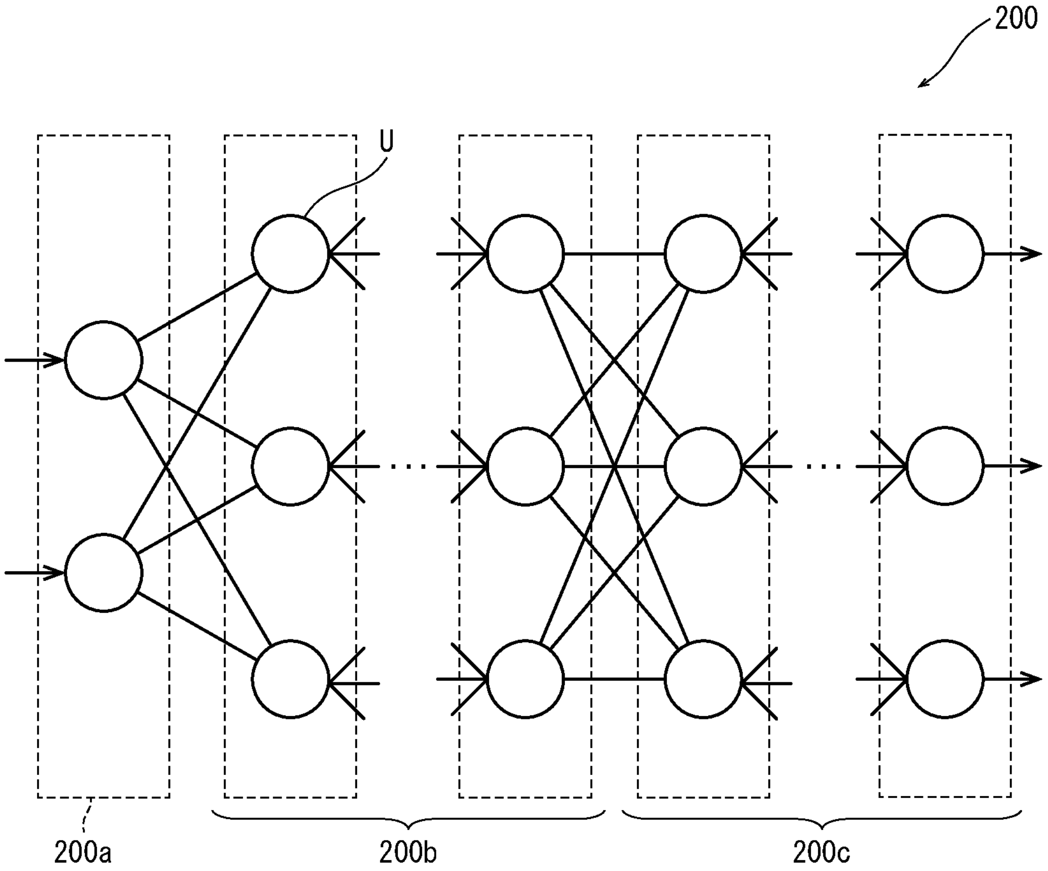


FIG. 3A

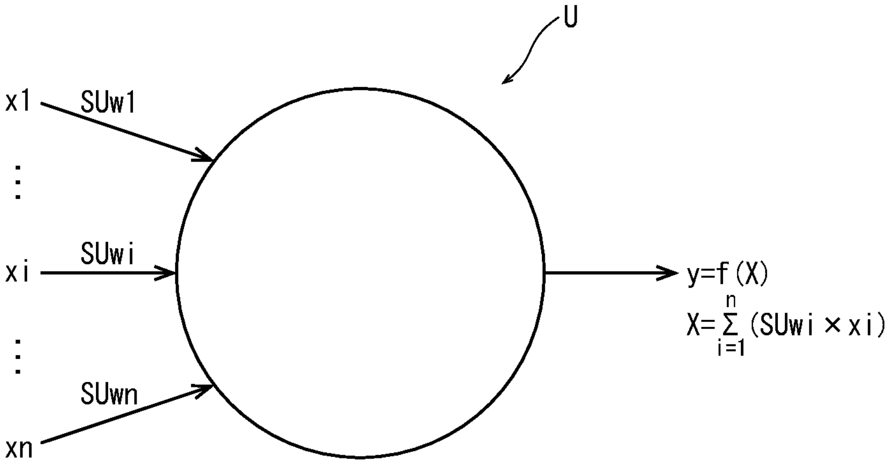
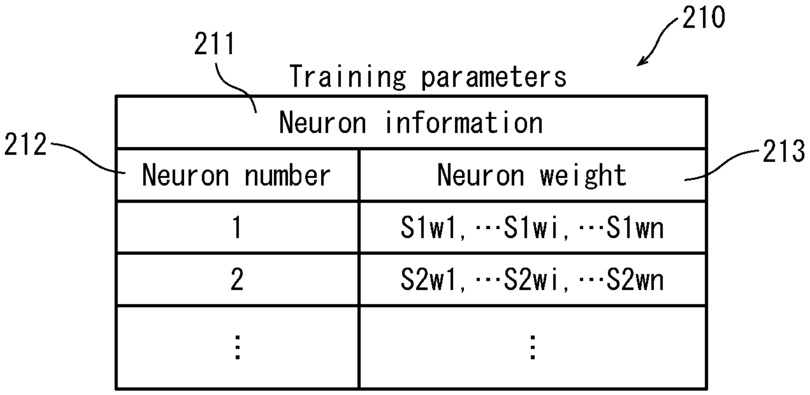


FIG. 3B


210
211
212
213

Training parameters

Neuron information	
Neuron number	Neuron weight
1	S1w1, ⋯S1wi, ⋯S1wn
2	S2w1, ⋯S2wi, ⋯S2wn
⋮	⋮

FIG. 4A

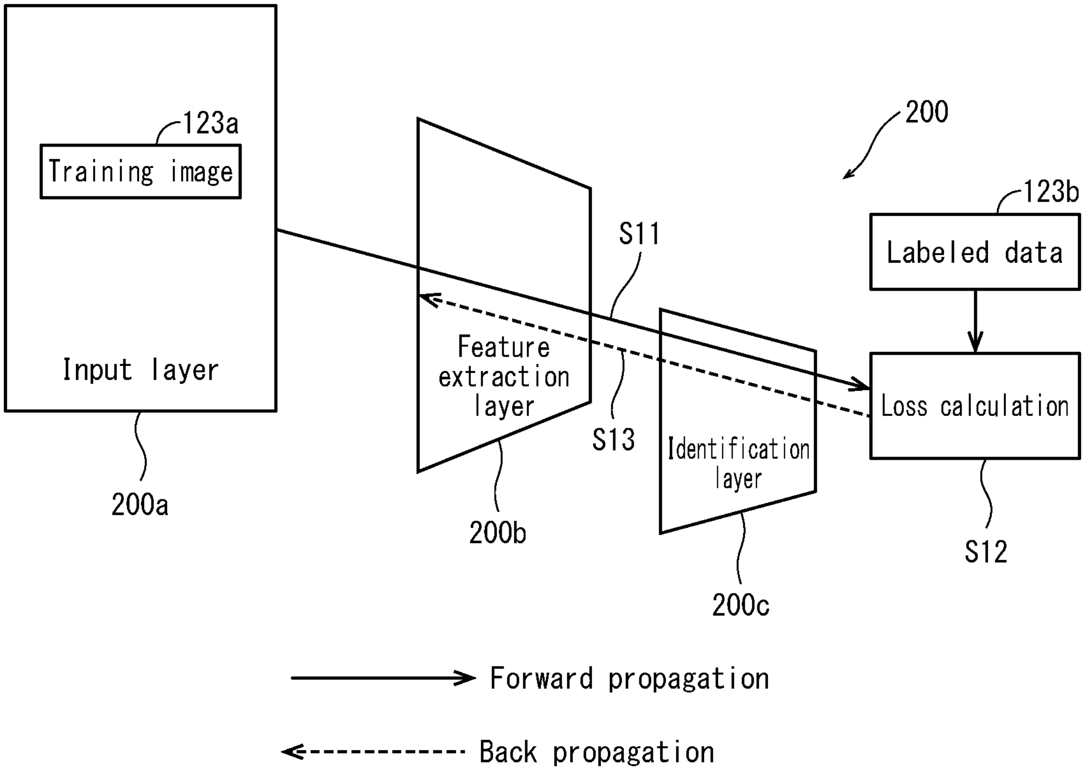

123a
Training image
Input layer
200a
Feature extraction layer
200b
S11
S13
Identification layer
200c
200
123b
Labeled data
Loss calculation
S12
Forward propagation
Back propagation

FIG. 4B

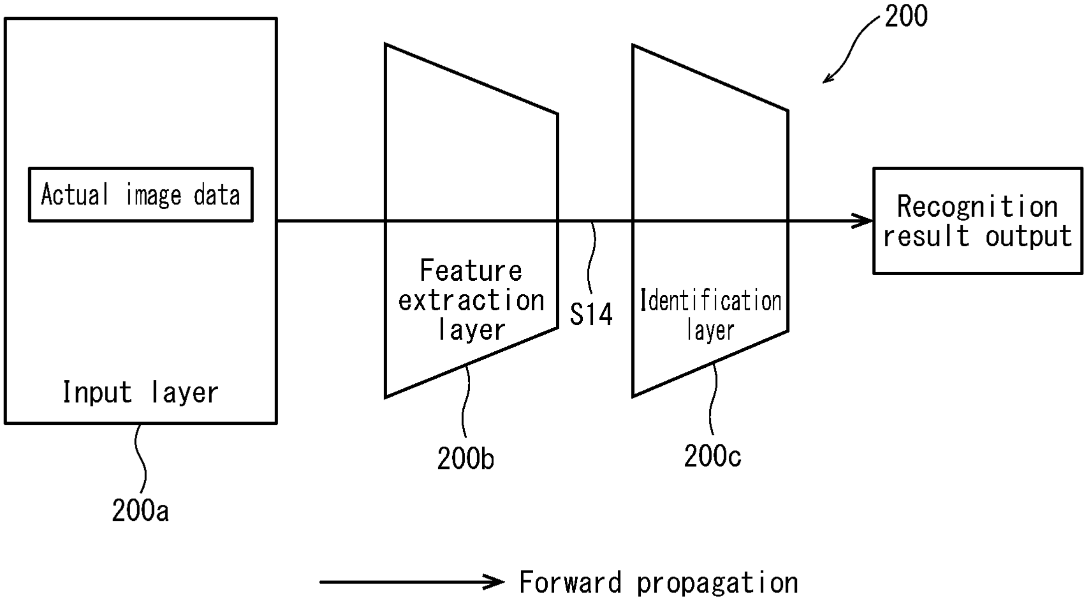

Actual image data
Input layer
200a
Feature extraction layer
200b
S14
Identification layer
200c
200
Recognition result output
Forward propagation

FIG. 5

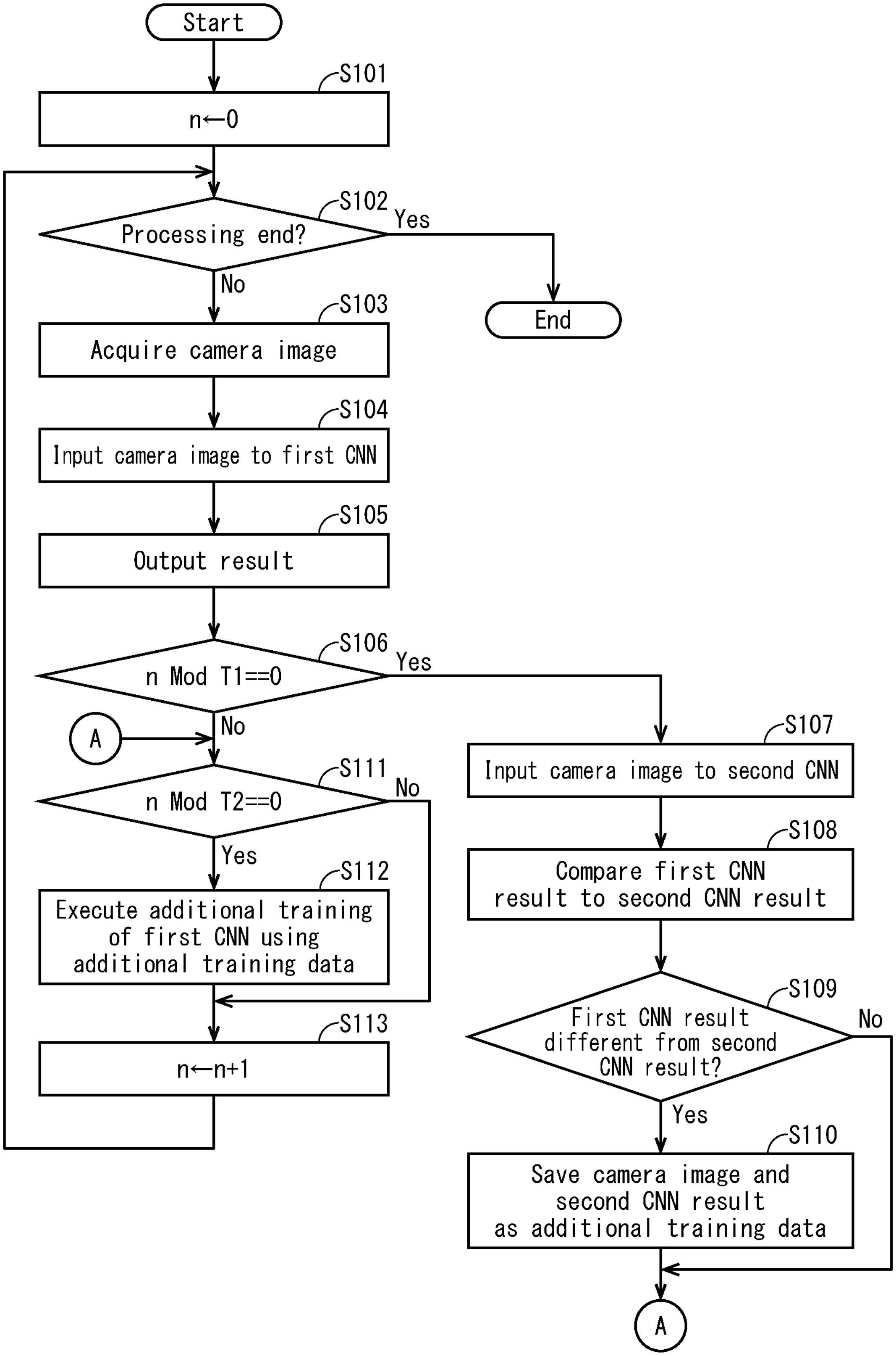

Start
S101
n←0
S102
Processing end?
Yes
End
No
S103
Acquire camera image
S104
Input camera image to first CNN
S105
Output result
S106
n Mod T1==0
Yes
No
A
S111
n Mod T2==0
No
Yes
S112
Execute additional training of first CNN using additional training data
S113
n←n+1
S107
Input camera image to second CNN
S108
Compare first CNN result to second CNN result
S109
First CNN result different from second CNN result?
No
Yes
S110
Save camera image and second CNN result as additional training data
A

FIG. 6

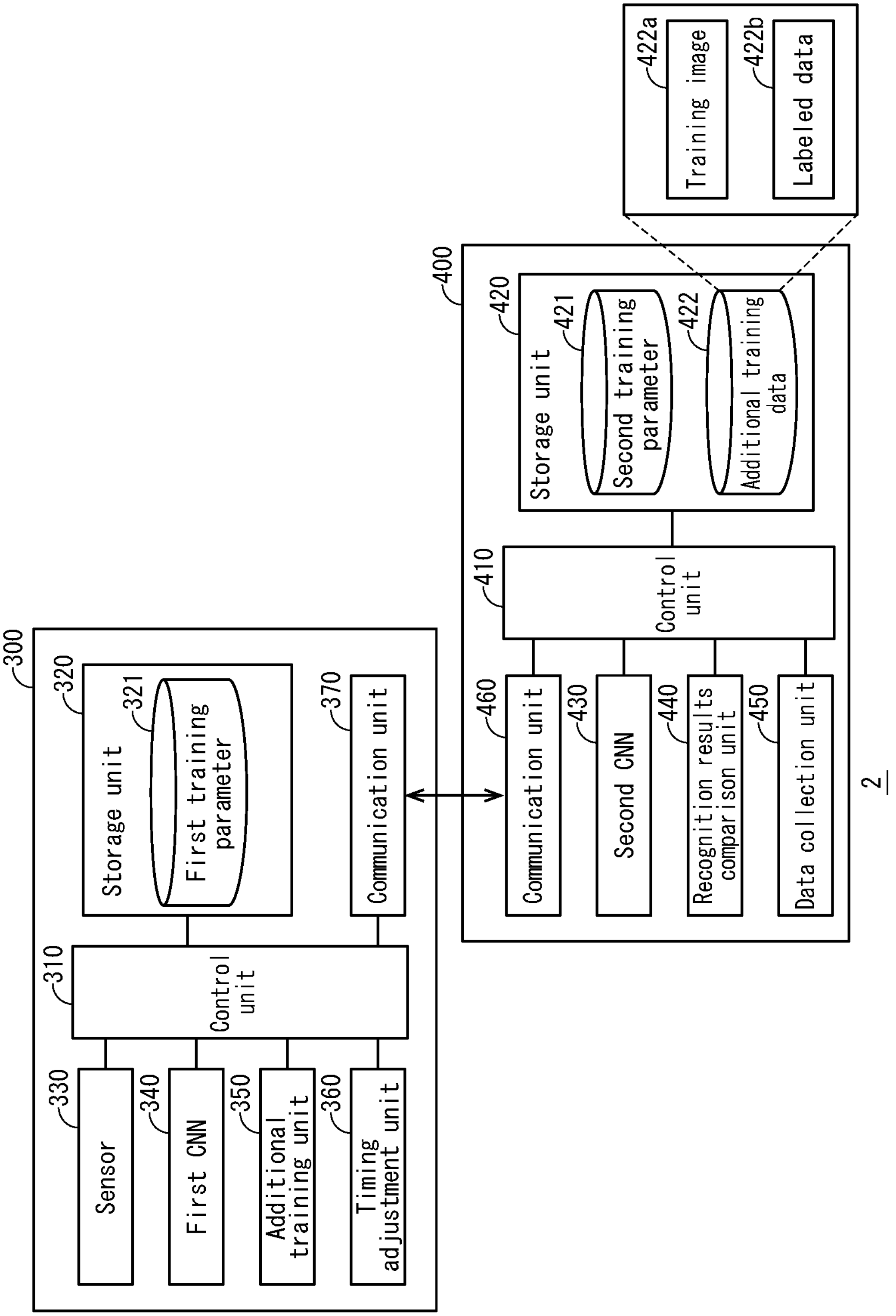

300
310
Control unit
320
Storage unit
321
First training parameter
330
Sensor
340
First CNN
350
Additional training unit
360
Timing adjustment unit
370
Communication unit
400
410
Control unit
420
Storage unit
421
Second training parameter
422
Additional training data
422a
Training image
422b
Labeled data
430
Second CNN
440
Recognition results comparison unit
450
Data collection unit
460
Communication unit
2

FIG. 7

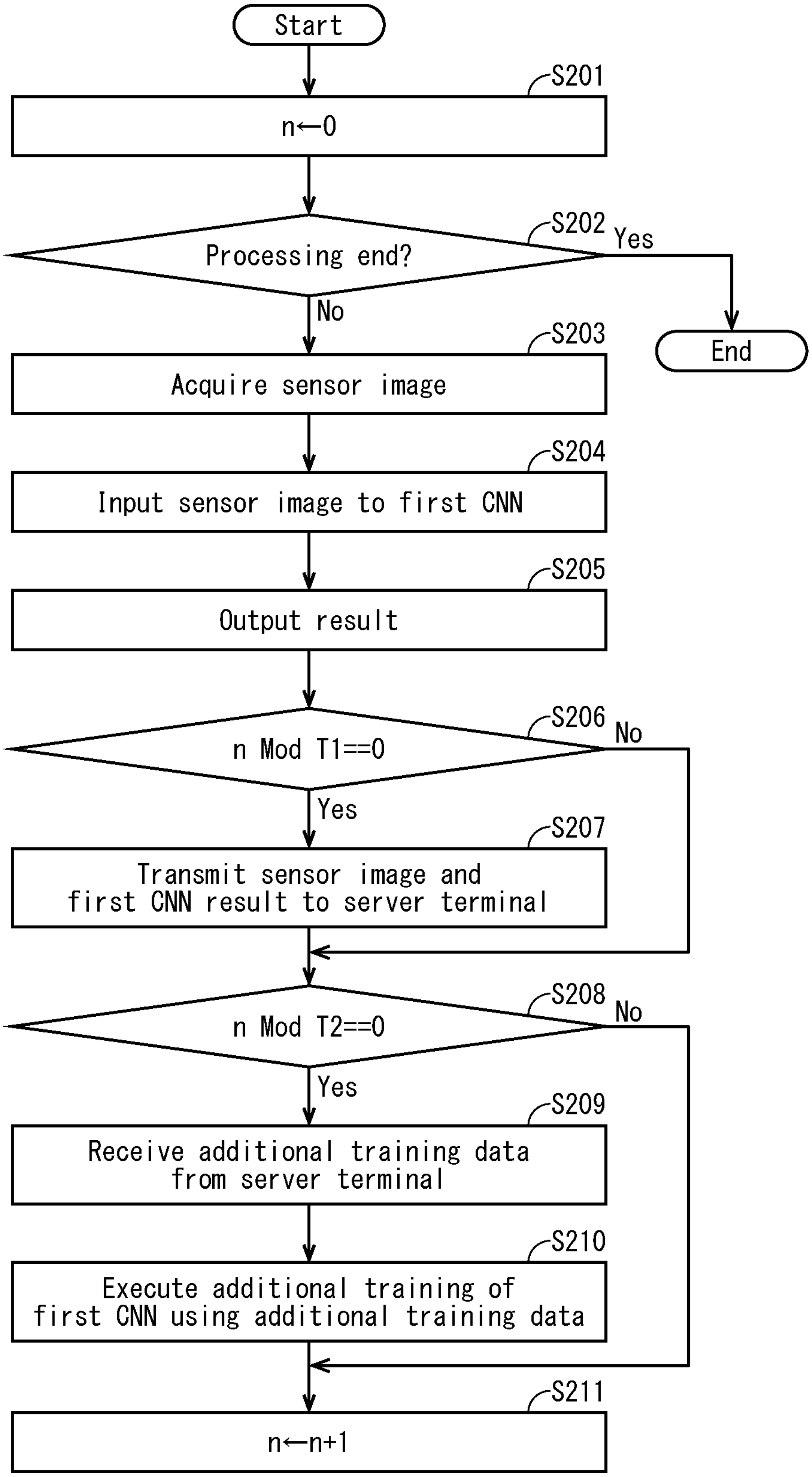
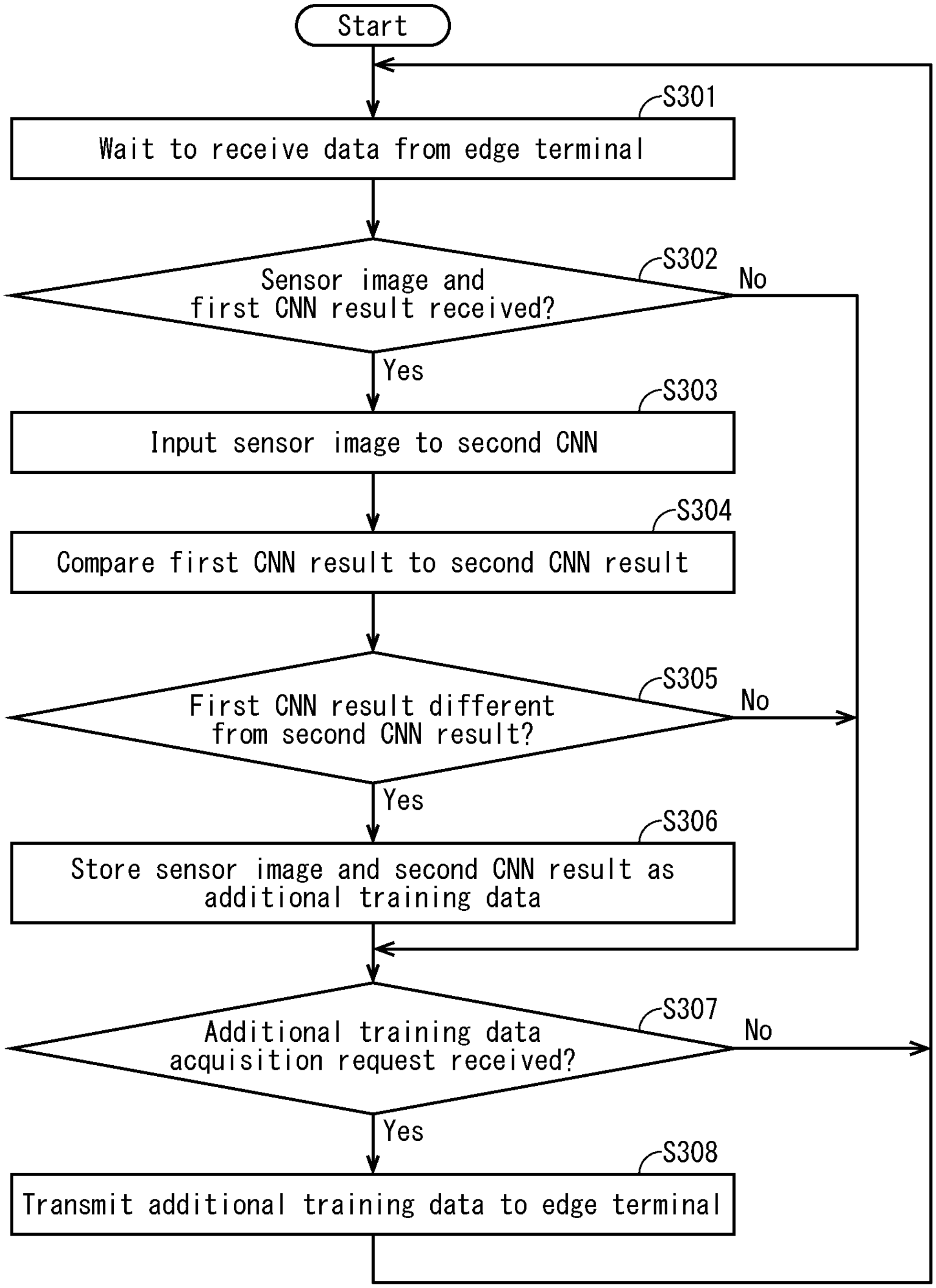

Start
S201
n←0
S202
Processing end?
Yes
End
No
S203
Acquire sensor image
S204
Input sensor image to first CNN
S205
Output result
S206
n Mod T1==0
No
Yes
S207
Transmit sensor image and first CNN result to server terminal
S208
n Mod T2==0
No
Yes
S209
Receive additional training data from server terminal
S210
Execute additional training of first CNN using additional training data
S211
n←n+1

FIG. 8


Start
S301
Wait to receive data from edge terminal
S302
Sensor image and first CNN result received?
No
Yes
S303
Input sensor image to second CNN
S304
Compare first CNN result to second CNN result
S305
First CNN result different from second CNN result?
No
Yes
S306
Store sensor image and second CNN result as additional training data
S307
Additional training data acquisition request received?
No
Yes
S308
Transmit additional training data to edge terminal

DATA COLLECTION DEVICE AND DATA COLLECTION METHOD

CROSS REFERENCE TO RELATED APPLICATION

This Application is a 371 of PCT/JP2021/022779 filed on Jun. 16, 2021, which, in turn, claims priority of Japanese Patent Application No. 2020-115540 filed on Jul. 3, 2020, and the above applications are incorporated herein by reference.

TECHNICAL FIELD

The present disclosure relates to technology for collecting training data used for training a data recognition model.

BACKGROUND ART

Conventionally, an image recognition system is known that recognizes a position and state of an object such as a person or car from an image, using machine learning.

For example, according to Patent Literature 1, a method has been proposed to execute training specialized for an installation site by adding an environment-dependent attribute corresponding to the installation site to training data, and executing the training using the training data that includes the environment-dependent attribute.

CITATION LIST

Patent Literature

[Patent Literature 1] Japanese Patent Application Publication No.: 2012-252507

SUMMARY OF INVENTION

Technical Problem

According to Patent Literature 1, in order to generate training data, a user needs to assign correct answers to images taken at an installation site. However, in order to improve recognition performance of a data recognition model, a large amount of training data is required, and in order to prepare a sufficient amount of training data for each of multiple installation sites, this becomes a problem in that a huge amount of work is required from a user.

A similar problem also exists when speech recognition or natural language processing using machine learning is executed.

The present disclosure is made in view of the above technical problems, and an object of the present disclosure is to provide a data collection device and a data collection method that can reduce user burden associated with generating training data for a data recognition model.

Solution to Problem

A data collection device according to an aspect of the present disclosure collects training data for a data recognition model, the data collection device comprising: a first recognition unit; a second recognition unit that is different from the first recognition unit; a comparison unit that compares a recognition result for input data by the first recognition unit to a recognition result for the input data by the second recognition unit; and a collection unit that collects the input data as training data according to a comparison result of the comparison unit.

According to at least one embodiment, computational scale of the first recognition unit is smaller than computational scale of the second recognition unit.

According to at least one embodiment, the collection unit collects the recognition result of the second recognition unit as training data, the training data indicating labeled data associated with the input data.

According to at least one embodiment, the data collection device further comprises a training unit that executes additional training of the first recognition unit using the training data collected by the collection unit.

According to at least one embodiment, the training unit corrects the labeled data according to an external input.

According to at least one embodiment, the comparison unit determines whether or not the recognition result of the first recognition unit and the recognition result of the second recognition unit are different, and the collection unit collects the input data as the training data when the recognition result of the first recognition unit and the recognition result of the second recognition unit are different.

According to at least one embodiment, the comparison unit determines whether or not a difference between the recognition result of the first recognition unit and the recognition result of the second recognition unit is equal to or greater than a defined threshold, and the collection unit collects the input data as the training data when the difference is equal to or greater than the threshold.

According to at least one embodiment, a timing determination unit that determines a timing of operation of the second recognition unit, wherein the first recognition unit regularly executes data recognition, and the second recognition unit executes data recognition at a timing determined by the timing determination unit.

According to at least one embodiment, the timing determination unit determines the timing at fixed intervals.

According to at least one embodiment, the timing determination unit determines the timing according to a training proficiency level of the first recognition unit.

According to at least one embodiment, the timing determination unit determines the timing according to an external input.

According to at least one embodiment, the data collection device further comprises an edge terminal comprising the first recognition unit; and a server terminal comprising the second recognition unit.

According to at least one embodiment, the data collection device further comprises at least one second edge terminal, the second edge terminal comprising a recognition unit that has the same configuration as the first recognition unit.

According to at least one embodiment, the first recognition unit and the second recognition unit execute image recognition, speech recognition, or natural language recognition.

A data collection method according an aspect of the present disclosure collects training data for a data recognition model, the data collection method comprising: a first recognition step of obtaining a recognition result for input data by a first recognition unit; a second recognition step of obtaining a recognition result for the input data by a second recognition unit different from the first recognition unit; a comparison step of comparing the recognition result of the first recognition unit to the recognition result of the second recognition unit; and a collection step of collecting the input data as training data according to a comparison result of the comparison step.

According to at least one embodiment, computational scale of the first recognition unit is smaller than computational scale of the second recognition unit.

According to at least one embodiment, the collection step collects the recognition result of the second recognition unit as training data, the training data indicating labeled data associated with the input data.

According to at least one embodiment, the data collection method further comprises additional training of the first recognition unit, executed using the training data collected in the collection step.

According to at least one embodiment, the comparison step determines whether or not the recognition result of the first recognition unit and the recognition result of the second recognition unit are different, and the collection step collects the input data as the training data when the recognition result of the first recognition unit and the recognition result of the second recognition unit are different.

According to at least one embodiment, the comparison step determines whether or not a difference between the recognition result of the first recognition unit and the recognition result of the second recognition unit is equal to or greater than a defined threshold, and the collection step collects the input data as the training data when the difference is equal to or greater than the threshold.

According to at least one embodiment, the first recognition unit regularly executes data recognition, and the second recognition unit executes data recognition at a defined timing.

Advantageous Effects of Invention

When there are recognition results from a first recognition unit and a second recognition unit, and recognition results from one recognition unit are correct and results from the other are wrong, input data for the wrong recognition unit is classified into false positive (FP) or false negative (FN). Here, FP means that input data does not contain a detection target, but is identified as including a detection target, while FN means that input data contains a detection target, but is identified as not including a detection target. In general, an object of training in data recognition is to reduce such FP and FN results. An effective method for reducing FP and FN results is add correct answers to data classified as FP or FN, generate training data, and execute additional training, such that correct recognition can be achieved with similar data. According to a data collection device of the present disclosure, such data classified as FP or FN can be easily collected as training data. Further, regarding correct answers, a user does not have to manually assign a correct answer and can instead use recognition results from a recognition unit that gave a correct answer. Therefore, user burden related to the generation of training data can be reduced.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a block diagram illustrating structure of an image recognition system **1**.

FIG. **2** is a block diagram illustrating structure of a convolutional neural network (CNN).

FIG. **3**A is a schematic diagram illustrating one neuron U of a CNN. FIG. **3**B is a diagram illustrating data structure of CNN trained parameters.

FIG. **4**A is a diagram schematically illustrating data propagation during training. FIG. **4**B is a diagram schematically illustrating data propagation during estimation.

FIG. **5** is a flowchart illustrating operation of the image recognition system **1**.

FIG. **6** is a block diagram illustrating structure of an image recognition system **2**.

FIG. **7** is a flowchart illustrating operation of an edge terminal **300**.

FIG. **8** is a flowchart illustrating operation of an edge terminal **400**.

DESCRIPTION OF EMBODIMENTS

1. Embodiment 1

An image recognition system **1** according to Embodiment 1 is described below.

1.1. Structure

FIG. **1** is a block diagram illustrating structure of the image recognition system **1**. As illustrated, the image recognition system **1** includes an image recognition device **100** and a camera **190**. The image recognition device **100** includes a control unit **110**, a non-volatile storage unit **120**, a first CNN **130** (first recognition unit), a second CNN **140** (second recognition unit), a recognition results comparison unit **150** (comparison unit), a data collection unit **160** (collection unit), a timing adjustment unit **170** (timing determination unit), and an additional training unit **180** (training unit).

Here, the first CNN **130**, the second CNN **140**, the recognition results comparison unit **150**, the data collection unit **160**, the timing adjustment unit **170**, and the additional training unit **180** constitute a data collection device.

The camera **190** includes an imaging element such as a complementary metal-oxide-semiconductor field-effect transistor (CMOS) image sensor or charge-coupled device (CCD) image sensor, and converts light imaged on the imaging element into an electric signal by photoelectric conversion to output an image of a defined size.

The camera **190** outputs images at a defined rate. For example, outputting images 30 frames per second (fps).

The control unit **110** includes a central processing unit (CPU), read-only memory (ROM), random access memory (RAM), and the like. The RAM is loaded with computer programs and data stored in the ROM and the storage unit **120**, and the CPU operates according the computer programs and data on the RAM so that each processing unit (the first CNN **130**, the second CNN **140**, the recognition results comparison unit **150**, the data collection unit **160**, the timing adjustment unit **170**, and the additional training unit **180**) is realized.

The storage unit **120** is, for example, configured as a hard disk. The storage unit **120** may be configured as a non-volatile semiconductor memory. The storage unit **120** stores a first training parameter **121**, a second training parameter **122**, and additional training data **123**. The additional training data **123** includes a training image **123***a* and labeled data **123***b*.

1.2. CNN

A neural network **200** illustrated in FIG. **2** is described as an example of a convolutional neural network.

(1) Structure of Neural Network **200**

The neural network **200**, as illustrated, is a hierarchical neural network that has an input layer **200***a*, a feature extraction layer **200***b*, and an identification layer **200***c*.

Here, a neural network is an information processing system that imitates a human neural network. In the neural network **200**, an engineered neuron model corresponding to a nerve cell is here called a neuron U. The input layer **200***a*, the feature extraction layer **200***b*, and the identification layer **200***c* are configured to each have a plurality of neurons U.

The input layer **200***a* is typically one layer. Neurons U of the input layer **200***a* receive, for example, pixel values of pixels forming an image. Received image values are output as-is from the neurons U of the input layer **200***a* to the feature extraction layer **200***b*. The feature extraction layer **200***b* extracts features from data received from the input layer **200***a* and outputs to the identification layer **200***c*. The feature extraction layer **200***b* is sometimes called a backbone network. The identification layer **200***c* performs identification using features extracted by the feature extraction layer **200***b*.

As a neuron U, an element with multiple inputs and one output is normally used, as illustrated in FIG. **3**A. Signals propagate in only one direction, and input signals xi(i=1, 2, . . . n) are multiplied by neuron weights (SUwi) on input to a neuron U. Neuron weights can be changed through training. The neuron U outputs a sum of the input values (SUwi×xi) each multiplied by neuron weights SUwi after transformation by an activation function f(X). That is, an output value y of a neuron U is represented by the following expression.

$$y=f(X)$$

Here,

$$X=\Sigma(\mathrm{SUwi}\times xi)$$

Note that, as the activation function, for example, a ReLU or a sigmoid function can be used.

As a training method of the neural network **200**, for example, an error is calculated using a defined error function between a value indicating a correct answer (labeled data) and an output value from the neural network **200**, and the error is minimized by an error backpropagation method in which neuron weights of the feature extraction layer **200***b* and the identification layer **200***c* are sequentially changed using a steepest descent method or the like.

(2) Training Process

The following describes a training process of the neural network **200**.

A training process is a process of training the neural network **200**. FIG. **4**A schematically illustrates a data propagation model of training process.

Training images **123***a* are input to the input layer **200***a* of the neural network **200** image by image, and output from the input layer **200***a* to the feature extraction layer **200***b*. Each neuron U of the feature extraction layer **200***b* executes an operation assigning neuron weight to the input data, and outputs data indicating an extracted feature to the identification layer **200***c*. Each neuron U of the identification layer **200***c* executes an operation assigning neuron weight to the input data (step S**11**). This provides object estimation based on the above features. Data indicating results of object estimation is output from the identification layer **200***c*.

An output value of the identification layer **200***c* is compared to labeled data (correct data) **123***b*, and an error (loss) is calculated using a defined error function (step S**12**). In order to reduce this error, neuron weights and the like of the identification layer **200***c* and neuron weights and the like of the feature extraction layer **200***b* are sequentially changed (back propagation) (step S**13**). In this way, the neural network **200** is trained.

(3) Training Results

Training results are stored in the storage unit **120** as training parameters. FIG. **3**B illustrates data structure of training parameters stored in the storage unit **120**. The training parameters are composed of neuron information **211**, as illustrated in FIG. **3**B. Each entry of the neuron information **211** corresponds to a neuron U of the feature extraction layer **200***b* or the identification layer **200***c*.

Each entry of the neuron information **211** includes a neuron number **212** and a neuron weight **213**.

The neuron number **212** is a number that identifies a neuron U of the feature extraction layer **200***b* or the identification layer **200***c*.

The neuron weight **213** is a neuron weight of a neuron U of the feature extraction layer **200***b* or the identification layer **200***c*.

A model trained in this way is called a data recognition model. A data recognition model is used to identify an object included in data.

(4) Estimation Process

The following describes an estimation process of the neural network **200**.

FIG. **4**B illustrates a data propagation model when estimating an object using the neural network **200** trained by the training process described above and using image data obtained by the camera **190** as input.

In the estimation process of the neural network **200**, feature extraction and object estimation are executed using the feature extraction layer **200***b* and the identification layer **200***c* that have been trained (step S**14**).

(5) First CNN **130**, Second CNN **140**

The image recognition system **1** includes two image recognition units (first CNN **130**, second CNN **140**). The first CNN **130** and the second CNN **140** are image recognition units that execute image recognition and, for example, person detection. If a person is detected in an image input from the camera **190**, a recognition result that a person is included is output, and if a person is not detected, a recognition result that a person is not included is output.

The first CNN **130** and the second CNN **140** each have the same configuration as the neural network **200**. CNNs differ in recognition speed (time required to recognize one image) and recognition accuracy (accuracy with which an input image can be correctly recognized) even if trained with the same training data, depending on computational scale. Computational scale varies depending on the CNN algorithm, the number of stages of the backbone network, and the like. Accordingly, recognition speed and recognition accuracy differ depending on CNN algorithm. Further, even with the same algorithm, if the number of stages of the backbone networks are different, recognition speed and recognition accuracy will be different. In general, the larger the computational scale, the higher the recognition accuracy, but the slower the recognition speed. Conversely, the smaller the computational scale, the faster the recognition speed, bur the lower the recognition accuracy.

The larger the number of stages in the backbone network, the larger the computational scale, and the smaller the number of stages in the backbone network, the smaller the computational scale.

The first CNN **130** and the second CNN **140** have different computational scales. The computational scale of the second CNN **140** is greater than that of the first CNN **130**. That is, the second CNN **140** has higher recognition accuracy than the first CNN **130** and the first CNN **130** has higher recognition speed than the second CNN **140**.

The first CNN **130** is an image recognition unit that executes image recognition in real time, and has a recognition speed that can complete image recognition within intervals between images output by the camera **190**. The second CNN **140** is an image recognition unit that executes image recognition only when instructed to by the timing adjustment unit **170**.

The first CNN **130** and the second CNN **140** are pre-trained using the same training data, the first training parameter **121** that is a training result of the first CNN **130** and the second training parameter **122** that is a training result of the second CNN **140** are stored in the storage unit **120**.

(6) Additional Training Unit **180**

The additional training unit **180** executes training of the first CNN **130** using additional training data **123** stored in the storage unit **120**, and updates the first training parameter **121** using training results.

1.3. Recognition Results Comparison Unit **150**

The recognition results comparison unit **150** acquires recognition results of the first CNN **130** and recognition results of the second CNN **140**, compares them, and outputs whether or not the recognition results match.

1.4. Data Collection Unit **160**

If the result of comparison by the recognition results comparison unit **150** is that the results are different, the data collection unit **160** acquires an input image input to the first CNN **130** and the second CNN **140** and recognition results from the second CNN **140**, generates additional training data **123** by using the input image as the training image **123*a*** and the recognition results of the second CNN **140** as the labeled data **123*b*** associated with the training image **123*a***, and stores the additional training data in the storage unit **120**.

1.5. Timing Adjustment Unit **170**

The timing adjustment unit **170** controls (determines) a timing of operation of the second CNN **140** and the additional training unit **180**.

1.6. Operation

FIG. **5** is a flowchart illustrating operation of the image recognition system **1**.

At a start of processing, the control unit **110** substitutes 0 for a control variable n indicating a frame number of an image for one frame acquired from the camera as an initial setting (step S**101**).

The control unit **110** determines whether or not a processing end interrupt has occurred (step S**102**), and if such an interrupt has occurred (step S**102**: Yes), ends processing.

If a processing end interrupt has not occurred (step S**102**: No), the control unit **110** acquires an image (camera image) of one frame from the camera **190** (step S**103**). The frame number of the camera image matches the control variable n. For example, when the control variable n is 1, the frame number of camera image is 1.

The control unit **110** inputs a camera image of frame number n to the first CNN **130** and causes execution of image recognition (step S**104**), and the first CNN **130** outputs a recognition result associated with the camera image of frame number n (step S**105**).

Next, the timing adjustment unit **170** determines whether or not a remainder obtained after dividing the control value n by a threshold T1 is 0 (step S**106**). If the determination result is true (step S**106**: Yes), it is determined that the second CNN **140** is to operate, and if the determination result is false (step S**106**: No), it is determined that second CNN **140** is not to operate. Here, the threshold T1 is a variable that specifies an interval at which the second CNN **140** is operated. When the output speed of the camera **190** is 30 fps and the threshold T1 is 1800, the second CNN **140** is operated once every 1800 frames, i.e., once every minute.

When the second CNN **140** is operated, the control unit **110** inputs the camera image of frame number n to the second CNN **140**, causes image recognition to be executed (step S**107**), and the second CNN **140** outputs a recognition result associated with the camera image of frame number n.

The recognition results comparison unit **150** acquires recognition results associated with the camera image of frame number n from the first CNN **130** and the second CNN **140**, compares them, and outputs a comparison result (step S**108**).

The data collection unit **160** acquires the comparison result from the recognition results comparison unit **150**, and if the recognition results are different (step S**109**: Yes), sets the camera image of frame number n as the training image **123*a***, sets the recognition result of the second CNN **140** associated with the camera image of frame number n as the labeled data **123*b*** for the training image **123*a***, generates additional training data **123** by combining the training image **123*a*** and the labeled data **123*b***, and stores the additional training data **123** in the storage unit **120** (step S**110**).

Next, the timing adjustment unit **170** determines whether or not a remainder obtained after dividing the control value n by a threshold T2 is 0 (step S**111**). If the determination result is true (step S**111**: Yes), it is determined that additional training of the first CNN **130** is to be executed, and if the determination result is false (step S**111**: No), it is determined that additional training of the first CNN **130** is not to be executed. Here, the threshold T2 is a variable that specifies an interval at which additional training of the first CNN **140** is executed. For example, if an output rate of the camera **190** is 30 fps and the threshold T2 is 18144000, then additional training of the first CNN **130** is executed once every 18144000 (**30** (frames)×60 (seconds)×60 (minutes)×24 (hours)×7 (days)) frames, i.e., once a week.

When executing additional training of the first CNN **130**, the additional training unit **180** uses the additional training data **123** stored in the storage unit **120** to execute the additional training of the first CNN **130** (step S**112**).

The control unit **110** then substitutes n+1 for the control variable n, and repeats processing from step S**102**.

Note that the following two processes can be executed in parallel.

(1) Processing of steps S**102** to S**106** and S**111** to S**113**.

(2) Processing of steps S**107** to S**110**.

Therefore, while the second CNN **140** is executing image recognition for the camera image of frame number n, the first CNN **130** may be executing image recognition for camera images of frame numbers n+1, n+2,

1.8. Effects

The image recognition system **1** includes two image recognition units with different computational scales, and causes them to execute image recognition on the same camera image. When one of the recognition results by the two image recognition units is correct and the other is wrong, the input image is classified as either FP or FN by the image recognition unit that made the mistake. Here, FP means that the input image does not contain a detection target, but is identified as including a detection target, while FN means that the input image contains a detection target, but is identified as not including a detection target. In general, an object of training in image recognition is to reduce such FP and FN results. An effective method for reducing FP and FN results is add correct answers to an image classified as FP or FN, generate training data, and execute additional training, such that correct recognition can be achieved with a similar image. According to the image recognition system **1** of the present disclosure, such images classified as FP and FN can be easily collected as training data. Further, regarding correct answers, a user does not have to manually assign a correct answer and can instead use recognition results from an image recognition unit that gave a correct answer. Therefore, user burden related to the generation of training data can be reduced.

2. Supplement

Although the present invention has been described above based on embodiments, the present invention is of course not limited to the embodiments described above, and the following modifications are of course included in the technical scope of the present invention.

(1) The image recognition system **1** of embodiment 1 described above includes two image recognition units (the first CNN **130** and the second CNN **140**) in the image recognition device **100** in the same housing. However, two image recognition units may be installed in different terminal devices.

FIG. **6** is a block diagram illustrating structure of an image recognition system **2** in which two image recognition units are installed in different terminal devices. As illustrated, the image recognition system **2** includes an edge terminal **300** and a server terminal **400**.

The edge terminal **300** includes a control unit **310**, a non-volatile storage unit **320**, a sensor **330**, a first CNN **340** (first recognition unit), an additional training unit **350** (training unit), a timing adjustment unit **360** (timing determination unit), and a communication unit **370**.

The control unit **310** is composed of a CPU, ROM, RAM, and the like. The RAM is loaded with computer programs and data stored in the ROM and the storage unit **320**, and the CPU operates according to the computer programs and data on the RAM to realize each processing unit (the first CNN **340**, the additional training unit **350**, and the timing adjustment unit **360**), and control the sensor **330** and the communication unit **370**.

The storage unit **320** is, for example, configured as a hard disk. The storage unit **320** may be configured as a non-volatile semiconductor memory. The storage unit **320** stores the first training parameter **321**.

The sensor **330** is an imaging element such as a CMOS image sensor or a CCD image sensor, and converts light imaged on the imaging element into an electric signal by photoelectric conversion to output an image of a defined size. The sensor **330** outputs images at a defined rate. For example, outputting images at 30 fps.

The first CNN **340** has the same configuration as the first CNN **130** of embodiment 1. The training result of the first CNN **340** is stored in the storage unit **320** as a first training parameter **321**.

The additional training unit **350** executes training of the first CNN **340** using additional training data **422** received from the server terminal **400**, and updates the first training parameter **321** using training results.

The timing adjustment unit **360** controls timing of operation of the additional training unit **350** and the second CNN **430** of the server terminal **400**.

The communication unit **370** is a network interface that communicates with the server terminal **400**. The edge terminal **300** transmits data such as an image captured by the sensor **330** and a recognition result of the first CNN **340** to the server terminal **400** via the communication unit **370**. Further, the edge terminal **300** receives, for example, additional training data **422** and the like from the server terminal **400** via the communication unit **370**.

The server terminal **400** includes a control unit **410**, a non-volatile storage unit **420**, the second CNN **430** (second recognition unit), a recognition results comparison unit **440** (comparison unit), a data collection unit **450** (collection unit), and a communication unit **460**.

The control unit **410** is composed of a CPU, ROM, RAM, and the like. The RAM is loaded with computer programs and data stored in the ROM and the storage unit **420**, and the CPU operates according to the computer programs and data on the RAM, to realize each processing unit (the second CNN **430**, the recognition results comparison unit **440**, and the data collection unit **450**) and control the communication unit **460**.

The storage unit **420** is, for example, configured as a hard disk. The storage unit **420** may be configured as a non-volatile semiconductor memory. The storage unit **420** stores a second training parameter **421** and additional training data **422**. The additional training data **422** includes a training image **422***a* and labeled data **422***b*.

The second CNN **430** has the same configuration as the second CNN **140** of embodiment 1. The training result of the second CNN **430** is stored in the storage unit **420** as the second training parameter **421**.

The recognition results comparison unit **440** has the same configuration as the recognition results comparison unit **150** of embodiment 1, acquires a recognition result of the first CNN **340** and the recognition result of the second CNN **430**, compares them, and outputs a result of whether or not the recognition results match.

The data collection unit **450** has the same configuration as the data collection unit **160** of embodiment 1. As a result of the comparison by the recognition results comparison unit **440**, if the results are different, the data collection unit **450** acquires the input image input to the first CNN **340** and the second CNN **430** and the recognition result of the second CNN **430**, generates additional training data **422** by combining the input image as the training image **422***a* and the recognition result of the second CNN **430** as the labeled data **422***b* associated with the training image **422***a*, and stores the additional training data **422** in the storage unit **420**.

The communication unit **460** is a network interface that communicates with the edge terminal **300**. The server terminal **400** receives data such as an image captured by the sensor **330** and a recognition result of the first CNN **340** from the edge terminal **300** via the communication unit **460**. Further, the server terminal **400** transmits, for example, the additional training data **422** and the like to the edge terminal **300** via the communication unit **460**.

FIG. **7** is a flowchart illustrating operation of the edge terminal **300**.

At a start of processing, the control unit **410** substitutes 0 for a control variable n indicating a frame number of an image for one frame acquired from the camera as an initial setting (step **S201**).

The control unit **410** determines whether or not a processing end interrupt has occurred (step S**202**), and if such an interrupt has occurred (step S**202**: Yes), ends processing.

If a processing end interrupt has not occurred (step S**202**: No), the control unit **410** acquires an image (sensor image) of one frame from the sensor **330** (step S**203**). The frame number of the sensor image matches the control variable n. For example, when the control variable n is 1, the frame number of the sensor image is 1.

The control unit **310** inputs a sensor image of frame number n to the first CNN **340** and causes execution of image recognition (step S**204**), and the first CNN **340** outputs a recognition result associated with the sensor image of frame number n (step S**205**).

Next, the timing adjustment unit **360** determines whether or not a remainder obtained after dividing the control value n by the threshold T1 is 0 (step S**206**). If the determination result is true (step S**206**: Yes), it is determined that the second CNN **430** is to operate, and if the determination result is false (step S**206**: No), it is determined that the second CNN **430** is not to operate.

When causing the second CNN **430** to operate, the control unit **310** transmits a sensor image of frame number n and the recognition result of the first CNN **340** associated with the sensor image of frame number n to the server terminal **400** via the communication unit **370** (step S**207**).

Next, the timing adjustment unit **360** determines whether or not a remainder obtained after dividing the control value n by the threshold T2 is 0 (step S**208**). If the determination result is true (step S**208**: Yes), it is determined that additional training of the first CNN **340** is to be executed, and if the determination result is false (step S**208**: No), it is determined that additional training of the first CNN **340** is not to be executed.

When executing additional training of the first CNN **340**, the control unit **310** transmits an acquisition request for the additional training data **422** to the server terminal **400** via the communication unit **310**, and receives the additional training data **422** from the server terminal **400** in response (step S**209**). The additional training unit **350** executes additional training of the first CNN **340** using the additional training data **422** (step S**210**).

The control unit **310** then substitutes n+1 for the control variable n, and repeats processing from step S**202**.

FIG. **8** is a flowchart illustrating operations of the server terminal **400**.

The control unit **410** waits until data is received from the edge terminal **300** (step S**301**).

The control unit **410** determines whether the sensor image of frame number n and the recognition result of the first CNN **340** associated with the sensor image of frame number n have been received from the edge terminal via the communication unit **460** (step S**302**).

When receiving a sensor image of frame number n and the recognition result of the first CNN **340** associated with the sensor image of frame number n (step S**302**: Yes), the control unit **410** inputs the sensor image of frame number n to the second CNN **430**, causes image recognition to be executed (step S**303**), and the second CNN **430** outputs a recognition result associated with the camera image of frame number n.

The recognition results comparison unit **440** acquires recognition results for the sensor image of frame number n from the first CNN **430** and the second CNN **430**, compares them, and outputs a comparison result (step S**304**).

The data collection unit **450** acquires the comparison result from the recognition results comparison unit **440**, and if the recognition results are different (step S**305**: Yes), sets the sensor image of frame number n as the training image **422***a*, sets the recognition result of the second CNN **430** associated with the sensor image of frame number n as the labeled data **422***b* associated with the training image **422***a*, generates the additional training data **422** by combining the training image **422***a* and the labeled data **422***b*, and stores the additional training data **422** in the storage unit **420** (step S**306**).

The control unit **410** determines whether or not an acquisition request for the additional training data **422** has been received from the edge terminal **300** via the communication unit **460** (step S**307**).

On receiving an acquisition request for the additional training data **422**, the control unit **410** transmits the additional training data **422** to the edge terminal **300** via the communication unit **460** in response.

Note that here, there is one of the edge terminal **300** associated with one of the server terminal **400**, but there may be a plurality of the edge terminal **300**.

(2) According to an embodiment described above, the recognition result of the second CNN **140** is described as the labeled data **123***b*, but user input may be received and the labeled data **123***b* corrected based on the user input.

(3) According to an embodiment described above, the first CNN **130** and the second CNN **140** are image recognition units that detect a person, and if a person is detected in an image input from the camera **190**, a recognition result that a person is included is output, and if a person is not detected, a recognition result that a person is not included is output, but a recognition result may be output as a numerical value such as a probability. In such a case, the data collection unit **160** may determine that recognition results are different when a difference between two numerical values exceeds a defined threshold and collect additional training data accordingly.

(4) According to an embodiment described above, the timing adjustment unit **170** causes operation of the second CNN **140** at defined time intervals T1, but timing for operation of the second CNN **140** is not limited to this. The timing of operation of the second CNN **140** may be changed according to the training proficiency level of the first CNN **130**. For example, an interval for operation of the second CNN **140** may be shortened in early stages of training, and lengthened in late stages of training. For example, a training proficiency level may be based on a number of image recognition executions by the first CNN **130**, where if the number of executions is less than a defined threshold, this is considered to be early training, and if the number of executions is greater than a defined threshold, this is considered to be late training. Further, based on a degree of matching between results of the first CNN **130** and the second CNN **140**, if the degree of matching is smaller than a defined threshold, this may be considered to be early training, and if the degree of matching is greater than the defined threshold, this may be considered to be late training.

Further, user input may be received and the interval T1 set according to the user input.

(5) According to an embodiment described above, the image recognition system that executes image recognition using machine learning includes two image recognition units with different computational scales that are made to execute image recognition on the same camera image. However, the present invention is not limited to this.

(a) A target of training and recognition may be audio data. In this case, examples of audio data may be music, human voices, sounds of nature, and the like. Examples of music include classical music, folk music, pop music, and latin music. Examples of human voices include news audio, lecture audio, and conversation audio. Examples of sounds of nature include birdsong, the sound of wind, and the sound of a flowing river. In an audio recognition system that executes audio recognition using machine learning, two audio recognition units (a first recognition unit and a second recognition unit) that have different computational scales execute audio recognition with respect to the same audio data obtained from an audio input device such as a microphone. For example, if the audio data is of a human voice, a voice of a specific person may be recognized.

(b) A target of training and recognition may be character data in natural language recognition processing. In this case, examples of character data include conversation sentences, literary works, newspaper articles, and academic papers. Further, examples of conversation sentences include conversations in Japanese, English, Italian, and the like. Further, examples of literary works include poems, novels, stories, plays, reviews, and essays. Further, examples of newspaper articles include political news, economic news, and scientific news. In a natural language processing system that executes natural language recognition using machine learning, two natural language recognition units (a first recognition unit and a second recognition unit) that have different computational scales execute natural language recognition with respect to the same character data. For example, if the character data is a newspaper article, the subject and predicate may be recognized and extracted from a sentence in the newspaper article.

(6) The above embodiments and modifications may be combined.

INDUSTRIAL APPLICABILITY

A data collection device according to the present disclosure can reduce user burden associated with generating training data, and is useful as a data collection device that collects training data.

REFERENCE SIGNS

100	Image recognition device
110	Control unit
120	Storage unit
130	First CNN
140	Second CNN
150	Recognition results comparison unit
160	Data collection unit
170	Timing adjustment unit
180	Additional training unit
190	Camera

The invention claimed is:

1. A data collection device that collects training data for a data recognition model, the data collection device comprising:

a first recognition unit, wherein the first recognition unit executes recognition processing on acquired input data and outputs a first recognition result based on the input data;

a second recognition unit that is different from the first recognition unit, wherein the second recognition unit executes recognition processing on the input data and outputs a second recognition result based on the input data;

a comparison unit that compares the first recognition result for the input data by the first recognition unit to the second recognition result for the input data by the second recognition unit; and

a collection unit that collects the input data as training data according to a comparison result of the comparison unit.

2. The data collection device of claim **1**, wherein

a computational scale of the first recognition unit is smaller than a computational scale of the second recognition unit.

3. The data collection device of claim **2**, wherein

the collection unit collects the second recognition result of the second recognition unit as training data, the training data indicating labeled data associated with the input data.

4. The data collection device of claim **3**, further comprising

a training unit that executes additional training of the first recognition unit using the training data collected by the collection unit.

5. The data collection device of claim **4**, wherein

the training unit corrects the labeled data according to an external input.

6. The data collection device of claim **1**, wherein

the comparison unit determines whether or not the first recognition result of the first recognition unit and the second recognition result of the second recognition unit are different, and

the collection unit collects the input data as the training data when the first recognition result of the first recognition unit and the second recognition result of the second recognition unit are different.

7. The data collection device of claim **1**, wherein

the comparison unit determines whether or not a difference between the first recognition result of the first recognition unit and the second recognition result of the second recognition unit is equal to or greater than a defined threshold, and

the collection unit collects the input data as the training data when the difference is equal to or greater than the threshold.

8. The data collection device of claim **1**, further comprising:

a timing determination unit that determines a timing of operation of the second recognition unit, wherein

the first recognition unit regularly executes data recognition, and

the second recognition unit executes data recognition at a timing determined by the timing determination unit.

9. The data collection device of claim **8**, wherein

the timing determination unit determines the timing at fixed intervals.

10. The data collection device of claim **8**, wherein

the timing determination unit determines the timing according to a training proficiency level of the first recognition unit.

11. The data collection device of claim **8**, wherein

the timing determination unit determines the timing according to an external input.

12. The data collection device of claim **1**, further comprising:

an edge terminal comprising the first recognition unit; and

a server terminal comprising the second recognition unit.

13. The data collection device of claim **12**, further comprising:

at least one second edge terminal, the second edge terminal comprising a recognition unit that has the same configuration as the first recognition unit.

14. The data collection device of claim **1**, wherein

the first recognition unit and the second recognition unit execute image recognition, speech recognition, or natural language recognition.

15. A data collection method that collects training data for a data recognition model, the data collection method comprising:

a first recognition step of obtaining a first recognition result for acquired input data by a first recognition unit;

a second recognition step of obtaining a second recognition result for the input data by a second recognition unit different from the first recognition unit, wherein each of the first recognition unit and the second recognition unit execute recognition processing on the input data;

a comparison step of comparing the first recognition result of the first recognition unit to the second recognition result of the second recognition unit; and

a collection step of collecting the input data as training data according to a comparison result of the comparison step.

16. The data collection method of claim **15**, wherein

a computational scale of the first recognition unit is smaller than a computational scale of the second recognition unit.

17. The data collection method of claim **16**, wherein

the collection step collects the second recognition result of the second recognition unit as training data, the training data indicating labeled data associated with the input data.

18. The data collection method of claim **17**, further comprising

additional training of the first recognition unit, executed using the training data collected in the collection step.

19. The data collection method of claim **15**, wherein

the comparison step determines whether or not the first recognition result of the first recognition unit and the second recognition result of the second recognition unit are different, and

the collection step collects the input data as the training data when the first recognition result of the first recognition unit and the second recognition result of the second recognition unit are different.

20. The data collection method of claim **15**, wherein

the comparison step determines whether or not a difference between the first recognition result of the first recognition unit and the second recognition result of the second recognition unit is equal to or greater than a defined threshold, and

the collection step collects the input data as the training data when the difference is equal to or greater than the threshold.

21. The data collection method of claim **15**, wherein

the first recognition unit regularly executes data recognition, and

the second recognition unit executes data recognition at a defined timing.

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