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Ebisuno

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(54) **ESTIMATION DEVICE, LEARNING DEVICE, TEACHING DATA CREATION DEVICE, ESTIMATION METHOD, LEARNING METHOD, TEACHING DATA CREATION METHOD, AND RECORDING MEDIUM FOR ESTIMATING SKELETON INFORMATION OF SUBJECT BASED ON IMAGE THEREOF**

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CPC . G06T 2207/30196; G06T 2207/20081; G06T 2207/20084; G06T 7/70;
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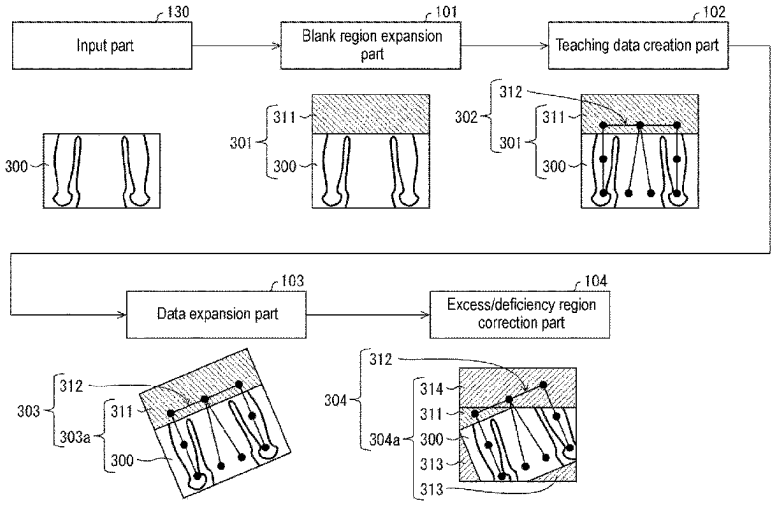
(57) **ABSTRACT**

In an image having a blank region, the present invention estimates skeleton information having a part of a joint in the blank region. An estimation device (**1**) is provided with: an input part (**130**) for acquiring a first image that includes a first joint and does not include a second joint of the subject; a blank region expansion part (**101**) for generating a second image from the first image by expanding the blank region; and an estimation part (**12**) for estimating, using the second image and a prelearned estimation model, skeleton information that includes the joint position of the second joint located in the blank region.

18 Claims, 10 Drawing Sheets



(51) **Int. Cl.**
G06T 7/60 (2017.01)
G06T 7/73 (2017.01)

(52) **U.S. Cl.**
CPC *G06T 2207/20044* (2013.01); *G06T 2207/20081* (2013.01); *G06T 2207/30196* (2013.01)

(58) **Field of Classification Search**
CPC G06T 7/75; G06V 40/23; G06V 10/82; G06V 10/25; G06V 2201/033; G06N 20/00
See application file for complete search history.

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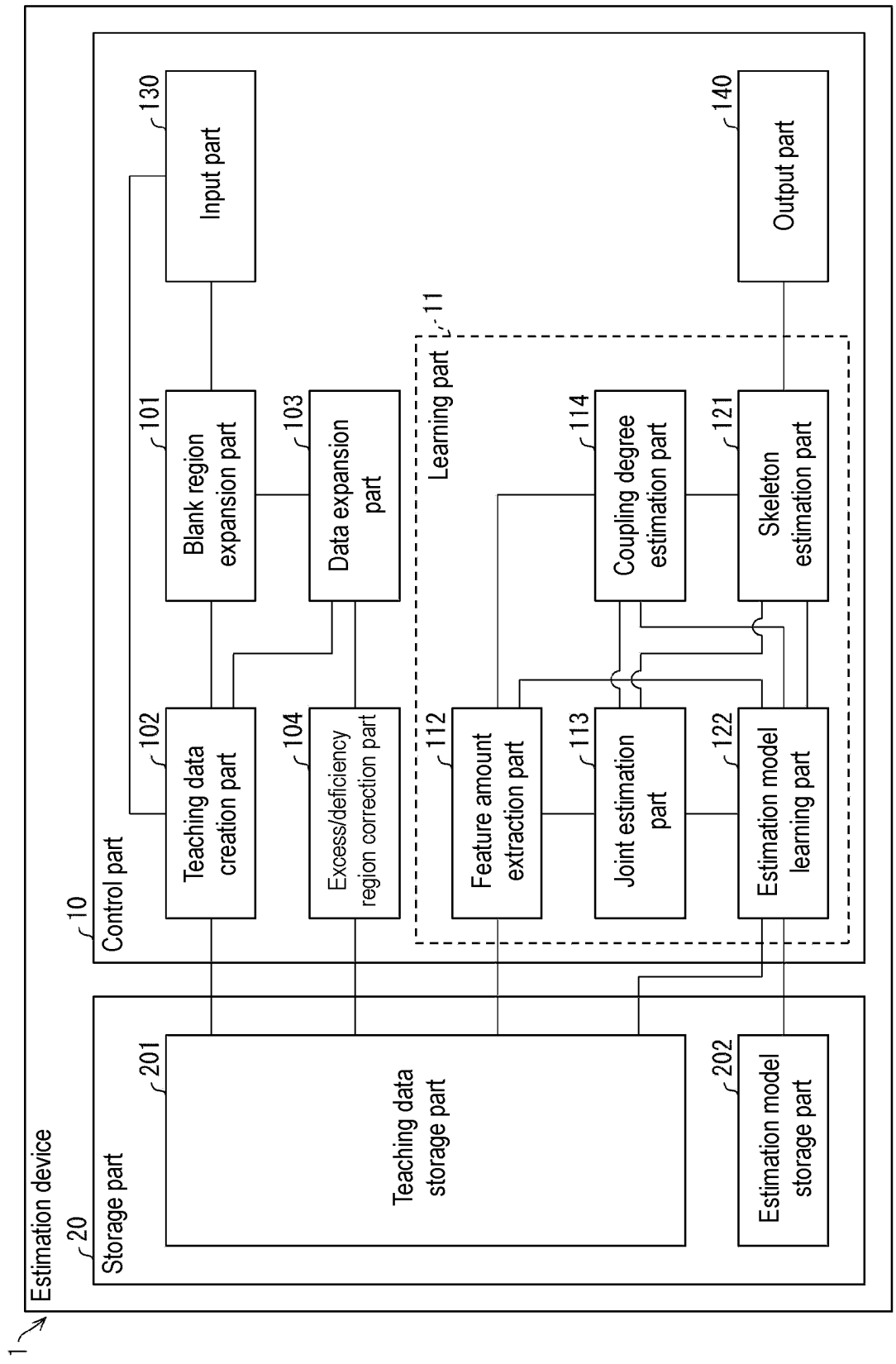
1
Estimation device
20
Storage part
201
Teaching data storage part
202
Estimation model storage part
10
Control part
102
Teaching data creation part
104
Excess/deficiency region correction part
101
Blank region expansion part
103
Data expansion part
130
Input part
11
Learning part
112
Feature amount extraction part
113
Joint estimation part
122
Estimation model learning part
114
Coupling degree estimation part
121
Skeleton estimation part
140
Output part

FIG. 1

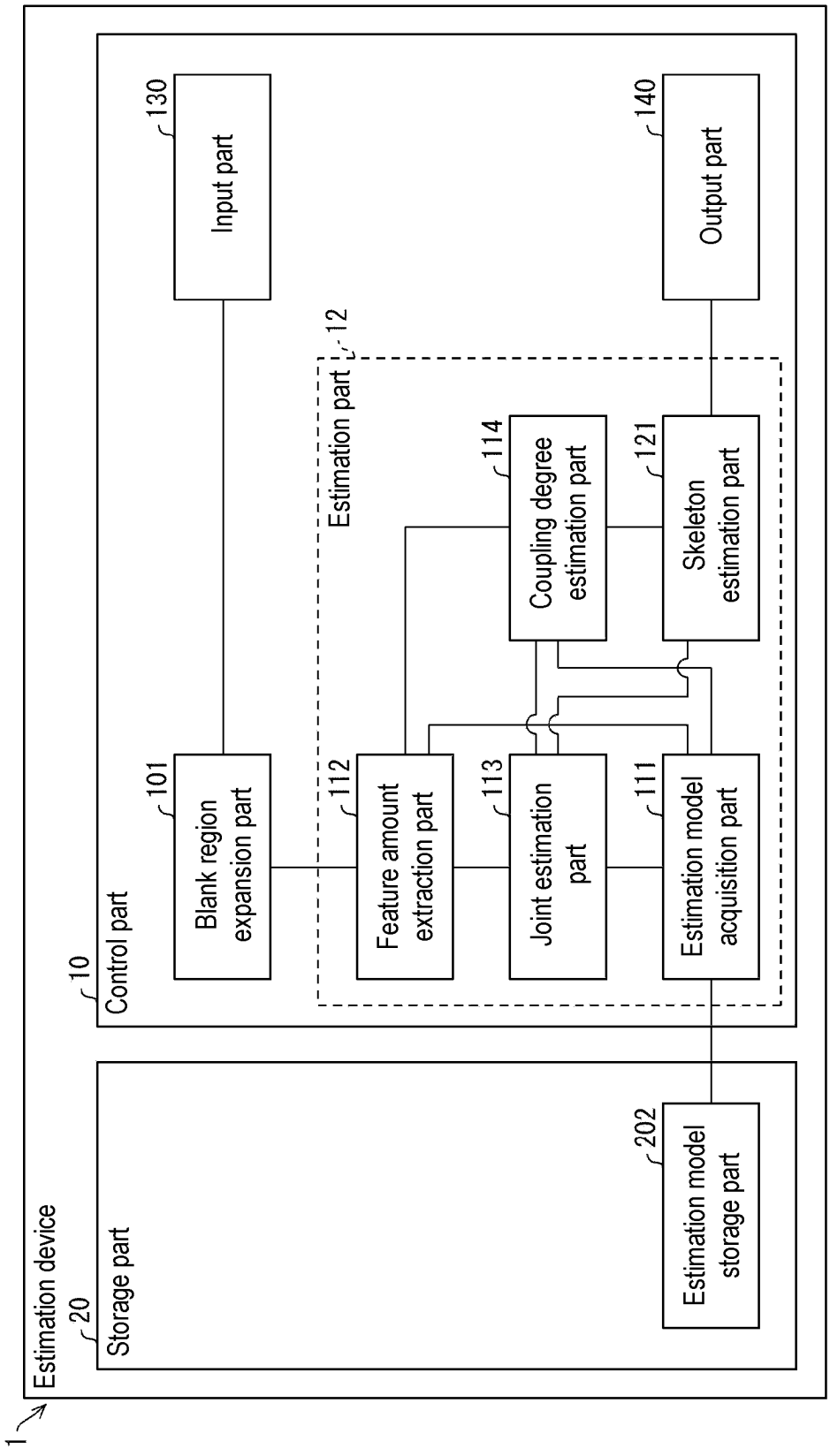
1
Estimation device
20
Storage part
202
Estimation model storage part
10
Control part
130
Input part
140
Output part
12
Estimation part
101
Blank region expansion part
112
Feature amount extraction part
113
Joint estimation part
111
Estimation model acquisition part
114
Coupling degree estimation part
121
Skeleton estimation part

FIG. 2

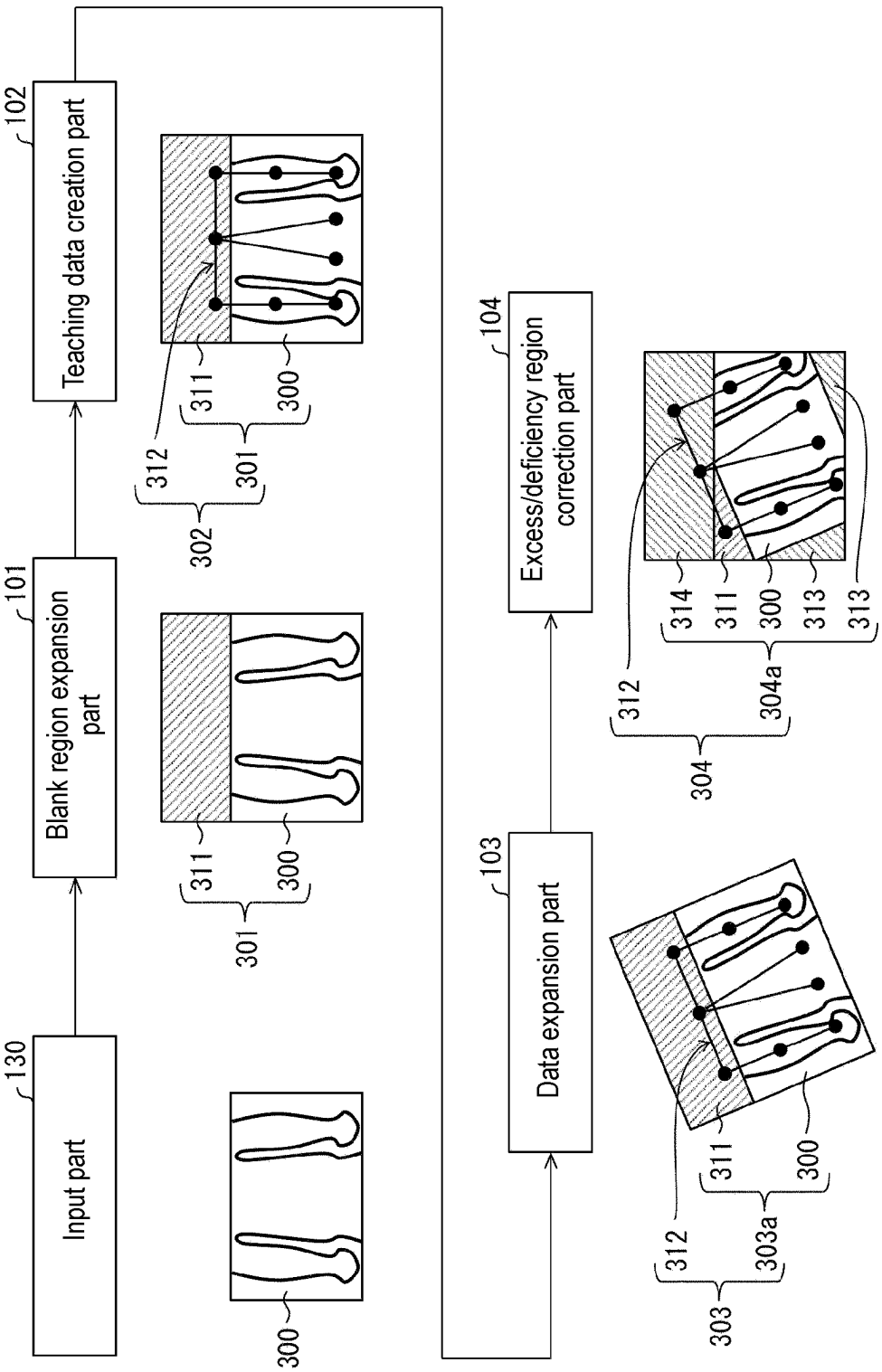
130
Input part
101
Blank region expansion part
102
Teaching data creation part
103
Data expansion part
104
Excess/deficiency region correction part
300
311
301
312
302
313
314
304
304a
303
303a

FIG. 3

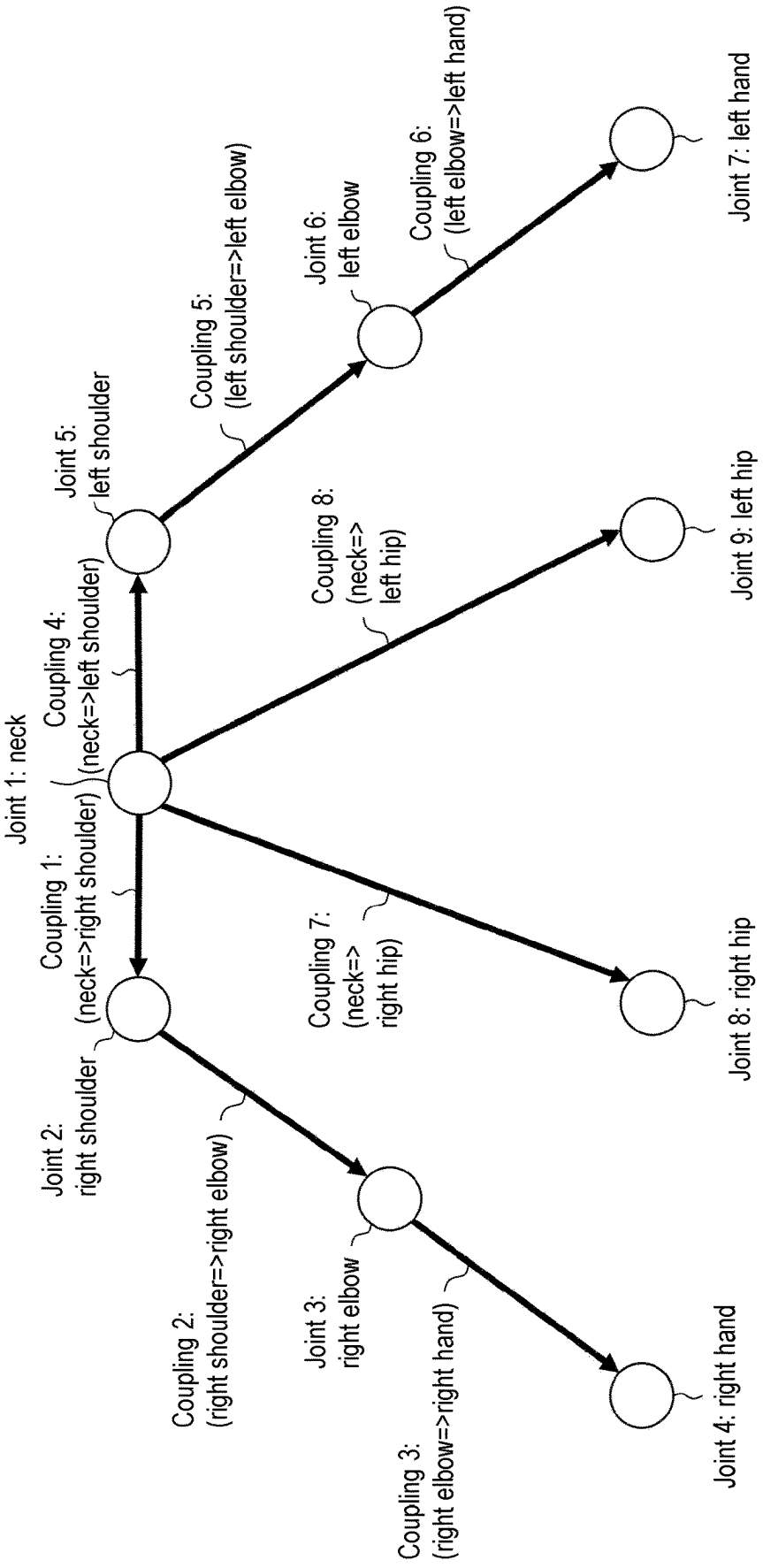
Joint 1: neck
Coupling 1: (neck=>right shoulder)
Coupling 4: (neck=>left shoulder)
Coupling 7: (neck=> right hip)
Coupling 8: (neck=> left hip)
Joint 2: right shoulder
Joint 5: left shoulder
Joint 8: right hip
Joint 9: left hip
Coupling 2: (right shoulder=>right elbow)
Coupling 5: (left shoulder=>left elbow)
Joint 3: right elbow
Joint 6: left elbow
Coupling 3: (right elbow=>right hand)
Coupling 6: (left elbow=>left hand)
Joint 4: right hand
Joint 7: left hand

FIG. 4

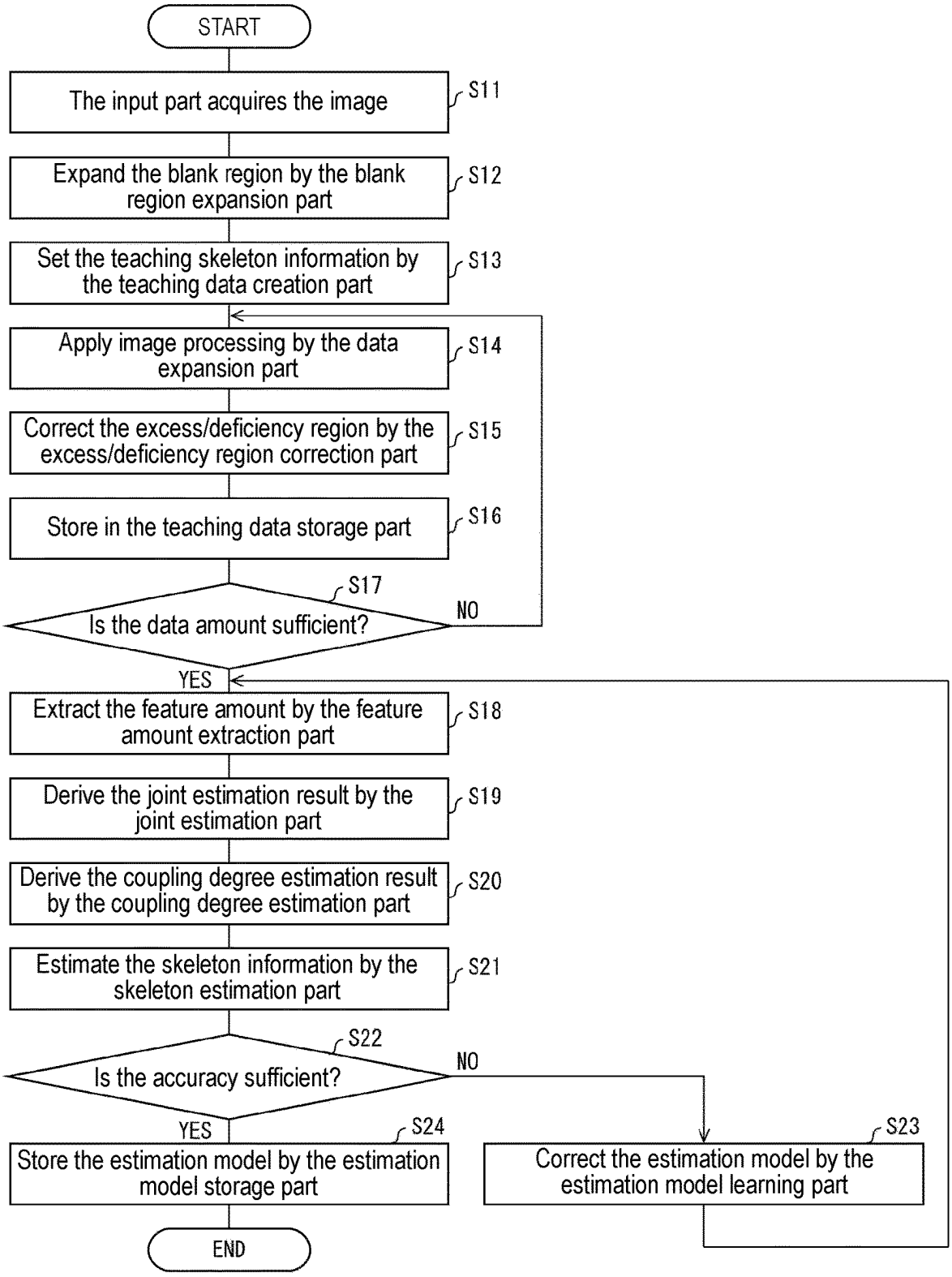
START
The input part acquires the image
S11
Expand the blank region by the blank region expansion part
S12
Set the teaching skeleton information by the teaching data creation part
S13
Apply image processing by the data expansion part
S14
Correct the excess/deficiency region by the excess/deficiency region correction part
S15
Store in the teaching data storage part
S16
S17
Is the data amount sufficient?
NO
YES
Extract the feature amount by the feature amount extraction part
S18
Derive the joint estimation result by the joint estimation part
S19
Derive the coupling degree estimation result by the coupling degree estimation part
S20
Estimate the skeleton information by the skeleton estimation part
S21
S22
Is the accuracy sufficient?
NO
YES
S24
Store the estimation model by the estimation model storage part
S23
Correct the estimation model by the estimation model learning part
END

FIG. 5

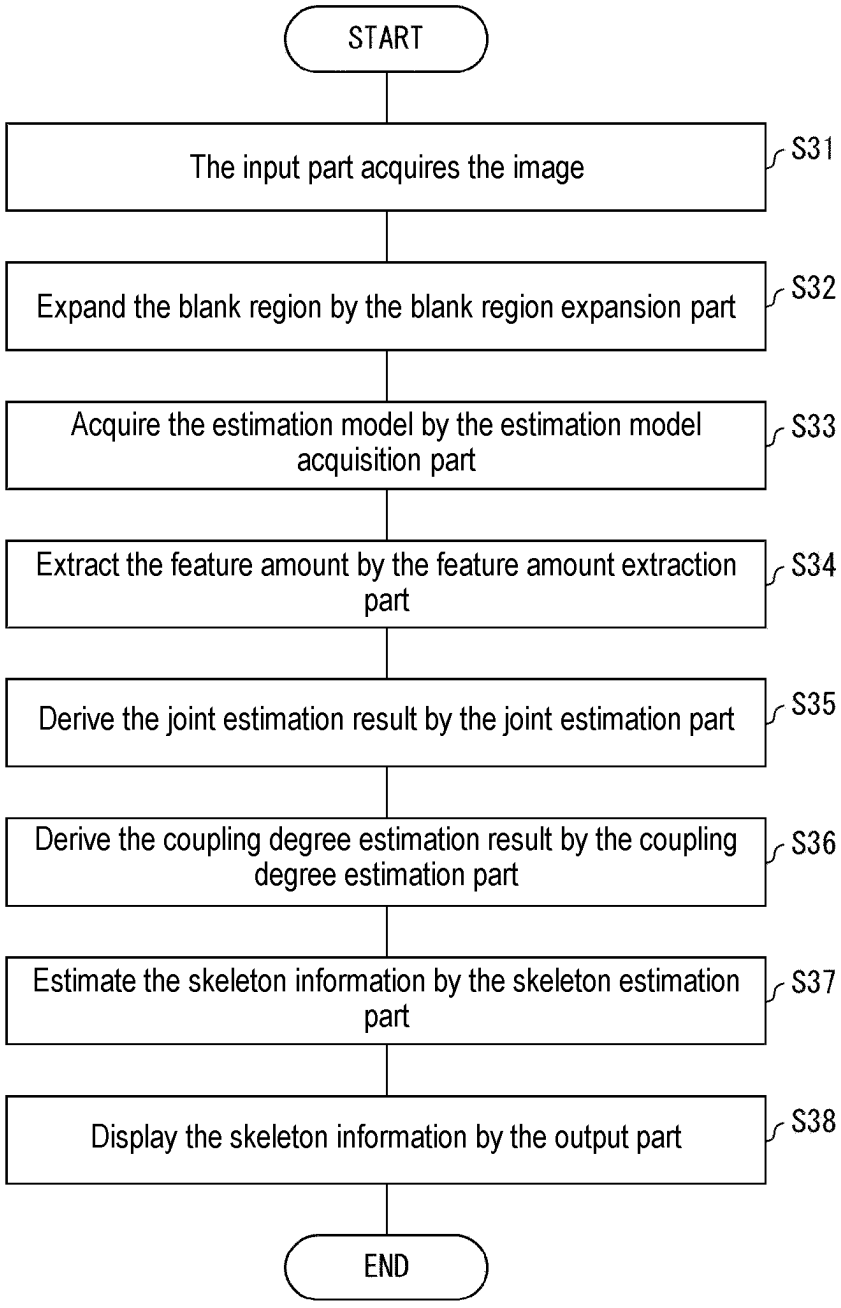
START
The input part acquires the image
S31
Expand the blank region by the blank region expansion part
S32
Acquire the estimation model by the estimation model acquisition part
S33
Extract the feature amount by the feature amount extraction part
S34
Derive the joint estimation result by the joint estimation part
S35
Derive the coupling degree estimation result by the coupling degree estimation part
S36
Estimate the skeleton information by the skeleton estimation part
S37
Display the skeleton information by the output part
S38
END

FIG. 6

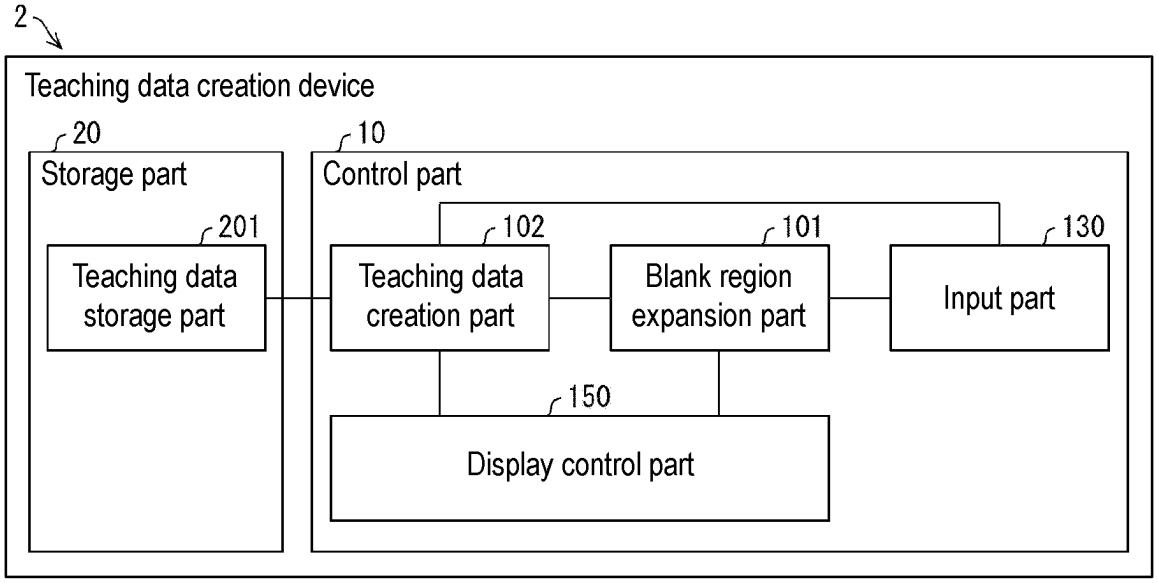
2
Teaching data creation device
20
Storage part
201
Teaching data storage part
10
Control part
102
Teaching data creation part
101
Blank region expansion part
130
Input part
150
Display control part

FIG. 7

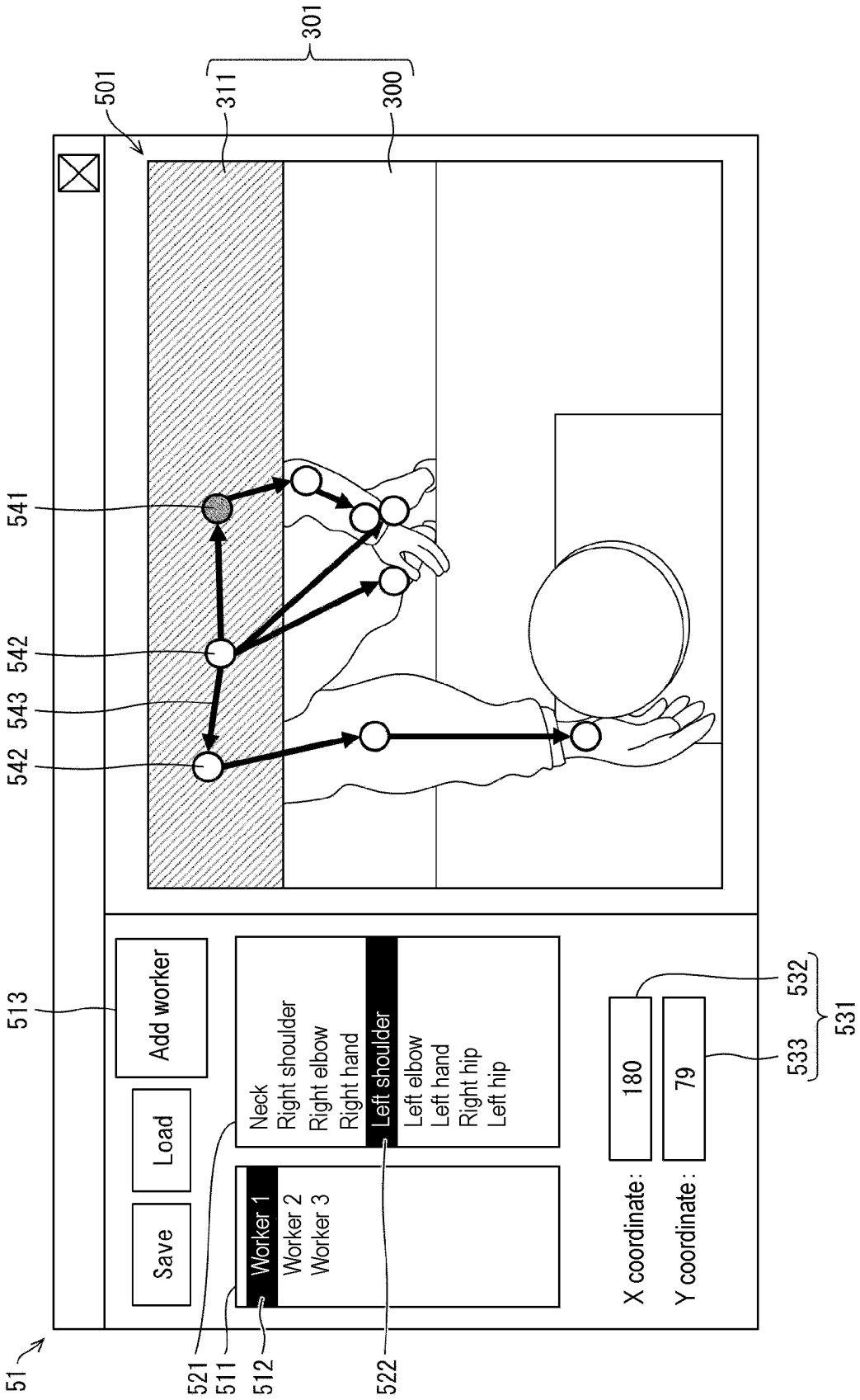
301
311
300
501
541
542
543
542
513
Add worker
Load
Save
Neck
Right shoulder
Right elbow
Right hand
Left shoulder
Left elbow
Left hand
Right hip
Left hip
Worker 1
Worker 2
Worker 3
X coordinate :
Y coordinate :
180
79
532
533
531
51
521
511
512
522

FIG. 8

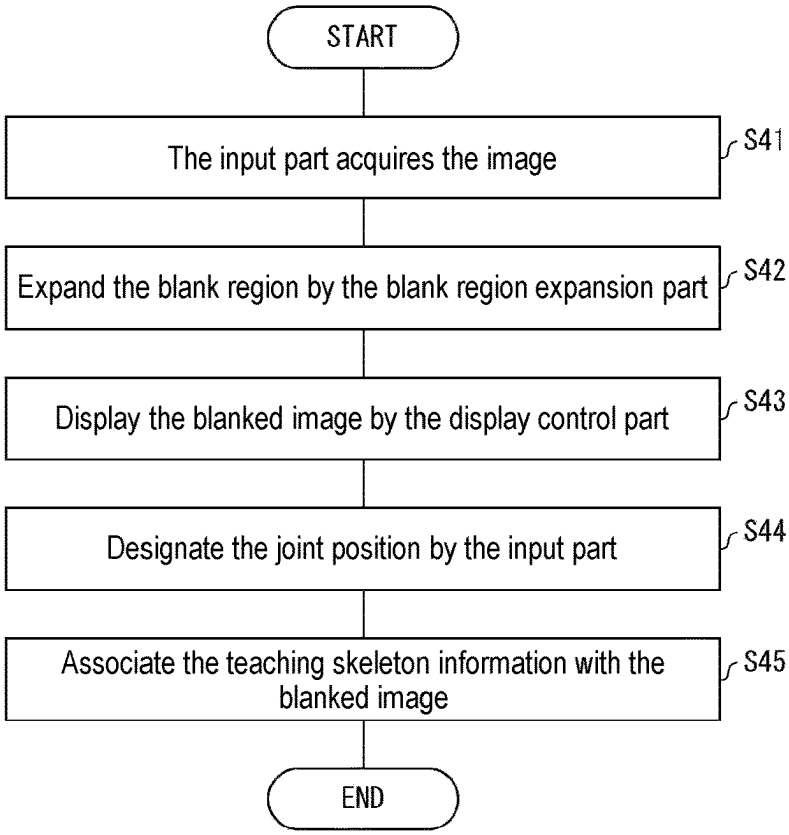
START
The input part acquires the image
S41
Expand the blank region by the blank region expansion part
S42
Display the blanked image by the display control part
S43
Designate the joint position by the input part
S44
Associate the teaching skeleton information with the blanked image
S45
END

FIG. 9

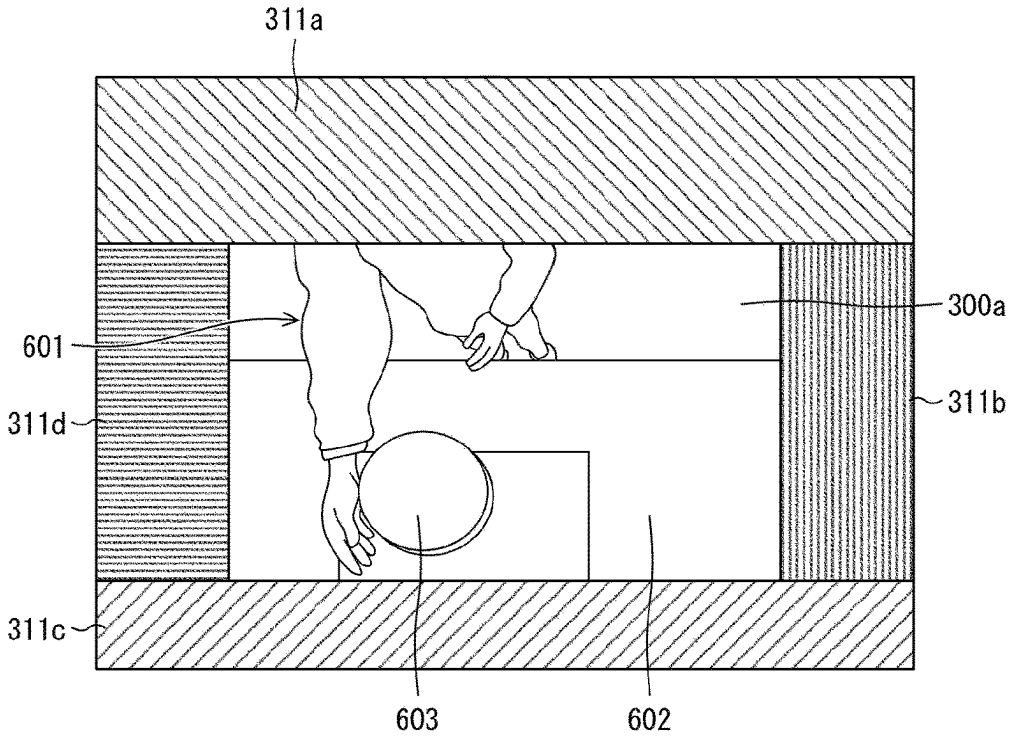
311a
300a
601
311b
311d
311c
603
602

FIG. 10

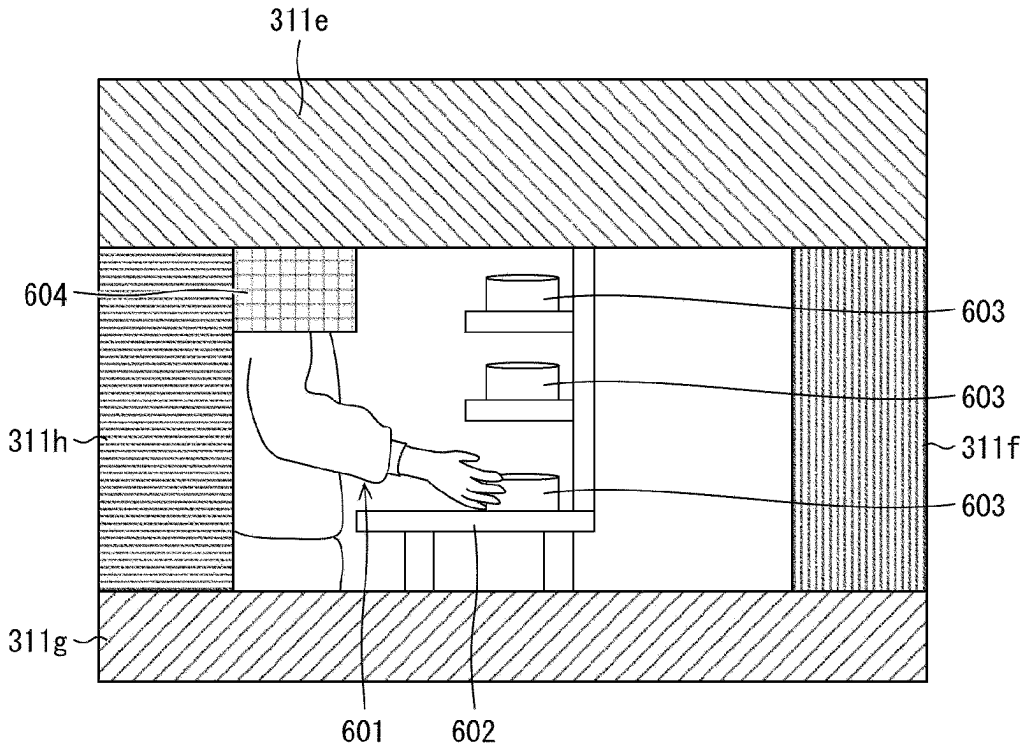

FIG. 11

ESTIMATION DEVICE, LEARNING DEVICE, TEACHING DATA CREATION DEVICE, ESTIMATION METHOD, LEARNING METHOD, TEACHING DATA CREATION METHOD, AND RECORDING MEDIUM FOR ESTIMATING SKELETON INFORMATION OF SUBJECT BASED ON IMAGE THEREOF

CROSS-REFERENCE TO RELATED APPLICATION

This application is a 371 application of the International PCT application serial no. PCT/JP2021/008703, filed on Mar. 5, 2021, which claims the priority benefits of Japan Patent Application No. 2020-074799, filed on Apr. 20, 2020. The entirety of each of the above-mentioned patent applications is hereby incorporated by reference herein and made a part of this specification.

TECHNICAL FIELD

The present invention relates to an estimation device or the like that estimates a skeleton position of a subject using an image of the subject.

RELATED ART

The work of factory workers (subject) is being improved by analyzing human movement. In the past, humans measure the work time by watching videos taken with a video camera to improve the work. Attempts to automate human motion analysis are also progressing, and skeleton estimation, which is estimation of the positions and correspondence relationship of joints using deep learning, is known as a conventional technique (see Non-Patent Literature 1).

CITATION LIST

Non-Patent Literature

[Non-Patent Literature 1] "OpenPose: Realtime Multi-Person 2D Pose Estimation using Part Affinity Fields", IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE, 2019

SUMMARY OF INVENTION

Technical Problem

However, for the conventional technique as described above, from the viewpoint of privacy protection and work analyticity on the work desk, it is required to photograph at an angle (for example, from above) where the face of the worker (subject) is not shown.

OpenPose relating to Non-Patent Literature 1 can be mentioned as the skeleton estimation based on the existing deep learning. In OpenPose, the skeleton cannot be stably estimated from an image that does not include the shoulder or neck joint due to the mechanism of the processing range.

One aspect of the present invention is to stably estimate skeleton information including a joint position of a joint of a subject from an image that does not include some joints of the subject.

Solution to Problem

In order to solve the above problem, an estimation device according to one aspect of the present invention includes an image acquisition part acquiring a first image that includes a first joint and does not include a second joint of a subject; a blank region expansion part generating a second image obtained by expanding the first image with a blank region; and an estimation part estimating skeleton information including a joint position of the second joint located in the blank region using the second image and a learned estimation model.

In order to solve the above problem, a learning device according to one aspect of the present invention includes an image acquisition part acquiring a first image that includes a first joint and does not include a second joint of a subject; a blank region expansion part generating a second image obtained by expanding the first image with a blank region; a teaching data storage part storing teaching data including skeleton information, which includes the second joint located in the blank region, and the second image; and a learning part learning an estimation model of skeleton information from the skeleton information and the second image using the teaching data.

In order to solve the above problem, a teaching data creation device according to one aspect of the present invention includes an image acquisition part acquiring a first image that includes a first joint and does not include a second joint of a subject; a blank region expansion part generating a second image obtained by expanding the first image with a blank region; a display control part displaying the second image; an input part receiving input of a joint position of the second joint with respect to the blank region in the second image from a user; and a teaching data creation part creating teaching data in which skeleton information including joint positions of the first joint and the second joint is associated with the second image.

An estimation method according to one aspect of the present invention includes an image acquisition step of acquiring a first image that includes a first joint and does not include a second joint of a subject; a blank region expansion step of generating a second image obtained by expanding the first image with a blank region; and an estimation step of estimating skeleton information including a joint position of the second joint located in the blank region using the second image and a learned estimation model.

A learning method according to one aspect of the present invention includes an image acquisition step of acquiring a first image that includes a first joint and does not includes a second joint of a subject; a blank region expansion step of generating a second image obtained by expanding the first image with a blank region; a teaching data acquisition step of acquiring teaching data including skeleton information, which includes the second joint located in the blank region, and the second image; and a learning step of learning an estimation model of skeleton information from the skeleton information and the second image using the teaching data.

A teaching data creation method according to one aspect of the present invention includes an image acquisition step of acquiring a first image that includes a first joint and does not include a second joint of a subject; a blank region expansion step of generating a second image obtained by expanding the first image with a blank region; a display control step of displaying the second image; an input step of receiving input of a joint position of the second joint with respect to the blank region in the second image from a user; and a teaching data creation step of creating teaching data in which skeleton information including joint positions of the first joint and the second joint is associated with the second image.

Effects of Invention

According to one aspect of the present invention, skeleton information including a joint located in a blank region can be estimated.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a block diagram showing an example of the components in the learning operation of the estimation device according to the first embodiment of the present invention.

FIG. **2** is a block diagram showing an example of the components in the estimation operation of the estimation device according to the first embodiment of the present invention.

FIG. **3** is a model diagram showing the state of data of the components in the learning operation of the estimation device according to the first embodiment of the present invention.

FIG. **4** is a schematic diagram of the skeleton information estimated by the estimation device according to the first embodiment of the present invention.

FIG. **5** is a flowchart showing the learning process of the estimation device according to the first embodiment of the present invention.

FIG. **6** is a flowchart showing the estimation process of the estimation device according to the first embodiment of the present invention.

FIG. **7** is a block diagram showing an example of the main configuration of the teaching data creation device according to the second embodiment of the present invention.

FIG. **8** is an example of the user interface for designating a joint position in the teaching data creation part according to the second embodiment of the present invention.

FIG. **9** is an operation flowchart of the teaching data creation device according to the second embodiment of the present invention.

FIG. **10** is a schematic diagram of the image of the worker taken from above according to the third embodiment of the present invention.

FIG. **11** is a schematic diagram of the image of the worker taken from a side according to the third embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

Hereinafter, an embodiment according to one aspect of the present invention (hereinafter, also referred to as "the present embodiment") will be described with reference to the drawings.

First Embodiment

1. Application Example

An estimation device is a device that estimates skeleton information of a worker using an image of the worker (subject). The skeleton information includes information of each joint position of the worker. The joint position of the worker represents a posture of the worker corresponding to a work operation.

Prior to the above estimation, the estimation device learns an estimation model used for the estimation. Specifically, the estimation device associates an image of the worker taken from above with skeleton information included in the image or composed of joint positions that can be inferred by a human, and generates it as teaching data. The estimation device learns the estimation model using the generated teaching data.

Since the image of the worker taken from above does not include the face of the worker, some joints of the worker, such as the neck joint, are not included. In the above learning, an image in which a blank region is set for an image of some missing joints is used for learning. Thereby, the estimation model that estimates the missing joint positions in the blank region is generated.

After generating the estimation model as described above, the image in which a part of a joint is missing is input to the estimation device and estimated using the estimation model, so that the skeleton information can be estimated while protecting privacy.

2. Configuration Example

A configuration example of an estimation device **1** will be described with reference to FIG. **1** to FIG. **4**. FIG. **1** is a block diagram showing an example of the components working in a learning operation among the components of the estimation device **1**. FIG. **2** is a block diagram showing an example of the components working in an estimation operation among the components of the estimation device **1**. FIG. **3** is a model diagram showing the state of data of the components in the learning operation of the estimation device **1**. FIG. **4** is a schematic diagram of the skeleton information estimated by the estimation device **1**.

As shown in FIG. **1** and FIG. **2**, the estimation device **1** (learning device) includes a control part **10** that integrates and controls each part of the estimation device **1**, and a storage part **20** that stores various data used by the estimation device.

The control part **10** includes a blank region expansion part **101**, a teaching data creation part **102**, a data expansion part **103**, an excess/deficiency region correction part **104**, an estimation model acquisition part **111**, a feature amount extraction part **112**, a joint estimation part **113**, a coupling degree estimation part **114**, a skeleton estimation part **121**, an estimation model learning part **122**, an input part **130**, and an output part **140**. Further, the storage part **20** includes a teaching data storage part **201** and an estimation model storage part **202**.

In the control part **10**, the learning part **11** works in the learning operation (see FIG. **1**), and the estimation part **12** works in the estimation operation (see FIG. **2**). The learning part **11** includes the feature amount extraction part **112**, the joint estimation part **113**, the coupling degree estimation part **114**, the skeleton estimation part **121**, and the estimation model learning part **122**. The estimation part **12** includes the estimation model acquisition part **111**, the feature amount extraction part **112**, the joint estimation part **113**, the coupling degree estimation part **114**, and the skeleton estimation part **121**.

The input part **130** (image acquisition part) receives data input including an image and user input to the estimation device **1**. The input part **130** receives input of an image **300** and outputs the image **300** to the blank region expansion part **101**. Further, the input part **130** may acquire the image **300** from a camera connected to the estimation device **1**, an external server via a network, or a storage device in the estimation device **1**. The input part **130** may support not only a still image but also a moving image.

The image **300** (first image) is an image showing a part of a joint of a worker, such as an elbow or hand joint, but another part of the joint of the worker, such as the neck or

shoulder, is missing. Since the image **300** does not include the face of the worker, for example, the privacy of the worker can be protected. The image **300** may be an image captured from above the worker, and in this case, it is easy to capture the situation in which the worker is working. By capturing the image from above, for example, it is possible to capture a change in the position of a work target on a work desk as the situation of working. The image **300** captured from above also does not include another part of the joint of the worker, such as the neck or shoulder.

In addition, the input part **130** also receives operation input to the estimation device **1** of the user via an input device. The input device may be, for example, a pointing device such as a mouse or a touch panel, or a cross key. The input part **130** receives from the user the designation of a joint position with respect to the image. The user input may be the position designated by the pointing device for a blanked image **301**, the position designated by the cross key, or the pixel coordinates of the blanked image **301** may be directly designated. The input part **130** outputs the input joint position information (teaching skeleton information **312**) to the teaching data creation part **102**.

The blank region expansion part **101** adds a blank region **311** adjacent to at least one side of the input image **300** to create a blanked image **301** with an expanded image range (image size). Thereafter, the blank region expansion part **101** outputs the blanked image **301** to the teaching data creation part **102** or the feature amount extraction part **112**.

The blanked image **301** (second image) is an image in which the image **300** and the blank region **311** are integrated. In FIG. **3**, the blank region **311** is shown by hatching that descends to the right, but is actually filled with a specific single color. The specific single color is, for example, black or white, but not limited thereto. The blank region **311** may be a region in which a specific pattern or hatching (the same pattern or hatching is applied to a plurality of blanked images **301**) is applied instead of a single color. Further, in FIG. **3**, the blank region **311** is adjacent to one side of the image **300**, but may be adjacent to two or more sides.

The size and arrangement of the blank region may be parameters that can be set by the user input.

The teaching data creation part **102** creates skeleton-containing data **302** (teaching data) in which the teaching skeleton information **312** is associated with the blanked image **301**. Thereafter, the teaching data creation part **102** outputs the skeleton-containing data **302** to the data expansion part **103**.

The skeleton-containing data **302** is data composed of the blanked image **301** and the teaching skeleton information **312**. The teaching skeleton information **312** includes information of the respective positions (joint positions) of multiple parts (neck, right shoulder, right elbow, right hand, left shoulder, left elbow, left hand, right hip, and left hip) of the worker corresponding to the blanked image **301**.

Here, there are nine joints (parts) set as the teaching skeleton information **312**, which are the neck, right shoulder, right elbow, right hand, left shoulder, left elbow, left hand, right hip, and left hip, but not limited thereto. The head and legs may be set, and some joints (right hand, etc.) may be missing. In FIG. **3**, for the teaching skeleton information **312**, the joints are shown by black circles and the coupling between the joints are shown by line segments.

The data expansion part **103** performs arbitrary image processing on the input skeleton-containing data **302** and creates image-processed data **303**. Thereafter, the image-processed data **303** is output to the excess/deficiency region correction part **104**.

The image-processed data **303** is data including an image-processed image **303***a* obtained by applying image processing to the blanked image **301**, and the teaching skeleton information **312** subjected to the same geometric deformation as the image processing. The geometric deformation includes left/right inversion, rotation, enlargement/reduction, left/right movement, up/down movement, and projective transformation.

The image processing includes brightness change, color change, and geometric deformation. The above image processing is not limited to one type at a time, and multiple types may be applied in order. Further, the skeleton-containing data **302** may be through-output as the image-processed data **303** to the excess/deficiency region correction part **104** without any image processing.

The excess/deficiency region correction part **104** (deficiency region correction part) sets a region having no image information among the pixels in the region of the original image size (the image size of the blanked image **301**) to a deficiency pixel region **313** for the image-processed image **303***a* of the input image-processed data **303**. The excess/deficiency region correction part **104** sets the same region as the blank region **311** of the original blanked image **301** to a blank region **314** again. The excess/deficiency region correction part **104** ignores the portion of the image-processed data **303** that extends beyond the region of the original image size. The excess/deficiency region correction part **104** corrects the deficiency pixel region **313** with a blank region in the image-processed image **303***a* (fills it with the same single color as the blank region **311**) to generate an excess/deficiency corrected image **304***a*.

The teaching data **304** includes the excess/deficiency corrected image **304***a* (second image) and the teaching skeleton information **312** subjected to the same geometric deformation as the image processing. The excess/deficiency region correction part **104** outputs the teaching data **304** to the teaching data storage part **201**.

In FIG. **3**, the deficiency pixel region **313** has hatching that rises to the right, but is actually filled with a single color that is the same color as the blank region **311**. Further, in the processing of the data expansion part **103**, the pixels in which the image disappears from the pixels in which the image was present before the image processing because the geometric deformation was performed as the image processing is also included in the above-mentioned deficiency pixel region **313**. In addition, the pixels extending from the original image region due to the geometric deformation are not included in the excess/deficiency corrected image **304***a*.

The teaching data storage part **201** stores the input teaching data **304**. Further, based on the instruction of the control part **10**, the teaching data **304** is output to the feature amount extraction part **112** and the estimation model learning part **122**.

The estimation model acquisition part **111** acquires the stored estimation model from the estimation model storage part **202**. The estimation model acquisition part **111** outputs (a plurality of parameters of) the estimation model to the feature amount extraction part **112**, the joint estimation part **113**, and the coupling degree estimation part **114**.

The feature amount extraction part **112** extracts the feature amount from the excess/deficiency corrected image **304***a* or the blanked image **301** constituting the input teaching data **304**. The feature amount extraction part **112** outputs the extracted feature amount to the joint estimation part **113** and the coupling degree estimation part **114**.

The joint estimation part **113** creates a joint estimation result representing the positions of a plurality of joints from

the input feature amount. The joint estimation part **113** outputs the joint estimation result to the skeleton estimation part **121**.

The coupling degree estimation part **114** obtains a coupling degree estimation result representing the coupling degree between joints from the input feature amount. The coupling degree estimation part **114** outputs the coupling degree estimation result to the skeleton estimation part **121**.

The skeleton estimation part **121** estimates the estimated skeleton information from the input joint estimation result and coupling degree estimation result. The skeleton estimation part **121** outputs the estimated skeleton information to the estimation model learning part **122** and the output part **140**.

The estimated skeleton information includes information of joint position corresponding to the worker of the image (excess/deficiency corrected image **304***a* or blanked image **301**) used for estimation. The estimated skeleton information can include the positions of some joints, such as the neck or shoulder, located in the blank region (**311** or **313**) in the image (excess/deficiency corrected image **304***a* or blanked image **301**) used for estimation.

As shown in FIG. **4**, in the estimation device **1**, nine joints which are the neck, right shoulder, right elbow, right hand, left shoulder, left elbow, left hand, right hip, and left hip are estimated as the joint estimation results. Furthermore, in the estimation device **1**, the degrees of coupling between eight joints which are neck and right shoulder, right shoulder and right elbow, right elbow and right hand, neck and left shoulder, left shoulder and left elbow, left elbow and left hand, neck and right hip, and neck and left hip are estimated as the coupling degree estimation result.

The skeleton estimation part **121** determines the position of each joint from the relative positional relationship of the joints, the rule of coupling set for each joint, and the relative strength of the coupling degree between the joints. In particular, when the image used for estimation includes a plurality of workers, the skeleton estimation part **121** identifies which worker each joint corresponds to using the coupling degree estimation result.

The estimation model learning part **122** compares the input estimated skeleton information with the teaching skeleton information **312** in the teaching data **304**. If sufficient estimation accuracy is not obtained, learning is continued, and the parameters of the feature amount extraction part **112**, the joint estimation part **113**, and the coupling degree estimation part **114** are corrected. Thereafter, in order to learn again, the current feature amount, the current joint estimation result, and the current coupling degree estimation result are output to the feature amount extraction part **112**, the joint estimation part **113**, and the coupling degree estimation part **114** to be processed again.

If sufficient estimation accuracy is obtained, the estimation model learning part **122** ends the learning, and stores the parameters of the feature amount extraction part **112**, the joint estimation part **113**, and the coupling degree estimation part **114** as an estimation model in the estimation model storage part **202**.

The estimation model storage part **202** stores the estimation model which is the parameters of the feature amount extraction part **112**, the joint estimation part **113**, and the coupling degree estimation part **114**. Further, the learned estimation model is output to the estimation model acquisition part **111**.

The output part **140** displays the estimated skeleton information by the estimation device **1** and outputs the data from the estimation device **1**.

3. Operation Example

(Learning Process)

A learning process of the estimation device **1** will be described with reference to FIG. **5**. FIG. **5** is a flowchart showing the learning process of the estimation device **1**.

The input part **130** acquires the image **300** (S**11**), and outputs the image **300** to the blank region expansion part **101**. The blank region expansion part **101** generates the blanked image **301** by expanding the image **300** by the blank region **311** (S**12**). The blank region expansion part **101** outputs the blanked image **301** to the teaching data creation part **102**.

The teaching data creation part **102** creates the skeleton-containing data **302** by associating the teaching skeleton information **312** corresponding to the image **300** with the blanked image **301** (S**13**). The teaching data creation part **102** outputs the skeleton-containing data **302** to the data expansion part **103**.

The data expansion part **103** generates the image-processed image **303***a* by applying image processing to the image (blanked image **301**) of the skeleton-containing data **302** (S**14**). At this time, in the image processing in which the pixel coordinates of the joint position change, such as rotation, enlargement/reduction, left/right movement, up/down movement, and projective transformation, the data expansion part **103** also applies the same deformation to the teaching skeleton information **312**. Accordingly, the data expansion part **103** generates the teaching skeleton information **312** corresponding to the image-processed image **303***a*. The data expansion part **103** outputs the image-processed data **303** including the image-processed image **303***a* and the teaching skeleton information **312** to the excess/deficiency region correction part **104**.

The excess/deficiency region correction part **104** sets the region having no image information in the region of the original image size (image size of the blanked image **301**) to the deficiency pixel region **313** for the image-processed image **303***a* of the image-processed data **303**. The excess/deficiency region correction part **104** corrects the excess/deficiency region (the deficiency pixel region **313** and the region extending beyond the region of the original image size). The region extending beyond the region of the original image size is ignored. The excess/deficiency region correction part **104** fills the deficiency pixel region **313** with a single color that is the same color as the blank region. Further, the excess/deficiency region correction part **104** sets the same region as the blank region **311** of the original blanked image **301** to the blank region **314** again for the image-processed image **303***a*. Accordingly, the excess/deficiency region correction part **104** creates the excess/deficiency corrected image **304***a* (S**15**). The deficiency pixel region **313** and the blank region **314** have the same color, but may have different colors.

The excess/deficiency region correction part **104** creates the teaching data **304** in which the geometrically deformed teaching skeleton information **312** and the excess/deficiency corrected image **304***a* are combined (S**15**). The excess/deficiency region correction part **104** stores the created teaching data **304** in the teaching data storage part (S**16**).

When the amount of teaching data stored in the teaching data storage part is less than a specified amount (No in S**17**), the process of creating the teaching data **304** from the skeleton-containing data **302** (data expansion processing of S**14** to S**16**) is repeated until the amount of teaching data reaches the specified amount. At this time, the image processing in the data expansion part **103** is different each time.

The type of image processing and the amount of change may be determined by random number parameters. When no image processing is performed, the skeleton-containing data **302** becomes the teaching data **304**.

When the amount of teaching data stored in the teaching data storage part **201** is equal to or greater than the specified amount (Yes in S**17**), the control part **10** ends the creation process of the teaching data and shifts to the learning process.

The learning part **11** reads the teaching data from the teaching data storage part **201**, and performs the learning process. The estimation model learning part **122** acquires the estimation model including a plurality of parameters from the estimation model storage part **202**. The estimation model is a model that inputs the image and outputs the estimated skeleton information. At the time of unlearning, the estimation model includes initial parameters. The estimation model learning part **122** outputs a plurality of corresponding parameters to the feature amount extraction part **112**, the joint estimation part **113**, and the coupling degree estimation part **114**.

The feature amount extraction part **112** extracts the feature amount from the excess/deficiency corrected image **304***a* in the teaching data **304** using the feature amount extraction parameter (S**18**). The joint estimation part **113** obtains the joint estimation result indicating the joint position based on the extracted feature amount using the joint estimation parameter (S**19**). The coupling degree estimation part **114** obtains the coupling degree estimation result indicating the coupling degree between the joints based on the extracted feature amount using the coupling degree estimation parameter (S**20**). The skeleton estimation part **121** obtains the estimated skeleton information from the joint estimation result and the coupling degree estimation result (S**21**).

The estimation model learning part **122** determines whether the estimated skeleton information has sufficient accuracy with respect to the teaching skeleton information **312** in the teaching data **304** (S**22**). The estimation model learning part **122** determines that the accuracy is sufficient if the difference between the estimated skeleton information and the teaching skeleton information is within a predetermined standard.

When the accuracy is not sufficient (No in S**22**), the estimation model learning part **122** corrects the parameters of the feature amount extraction part **112**, the joint estimation part **113**, and the coupling degree estimation part **114** (S**23**). In the correction, the estimation model learning part **122** corrects the parameters (learns the estimation model) so that the error between the estimated skeleton information and the teaching skeleton information **312** is reduced. The estimation model learning part **122** outputs the corrected parameters to the feature amount extraction part **112**, the joint estimation part **113**, and the coupling degree estimation part **114**. Thereafter, the learning part **11** repeats the processing of S**18** to S**21**. This is performed for a plurality of pieces of teaching data **304**.

When sufficient accuracy is obtained (Yes in S**22**), the learning process is completed, and the estimation model learning part **122** stores the learned estimation model in the estimation model storage part **202** (S**24**). The output part **140** displays on a display device that the learning has been completed.

In S**22** of FIG. **5**, the completion of the learning process is triggered by sufficient accuracy, but the present invention is not limited thereto, and the learning may be completed by performing repeated learning (processing from S**18** to S**23**) a predetermined number of times.

In addition, it is also possible to use OpenPose as similar processing from S**18** to S**24**.

(Estimation Process)

An estimation process of the estimation device **1** will be described with reference to FIG. **6**. FIG. **6** is a flowchart showing the estimation process of the estimation device **1**.

The input part **130** acquires the image **300** (S**31**), and outputs the image **300** to the blank region expansion part **101**. The blank region expansion part **101** generates the blanked image **301** by expanding the image **300** by the blank region **311** (S**32**). The blank region expansion part **101** outputs the blanked image **301** to the feature amount extraction part **112**.

The estimation model acquisition part **111** reads the learned estimation model from the estimation model storage part **202** (S**33**). The estimation model acquisition part **111** outputs a plurality of parameters included in the learned estimation model to the feature amount extraction part **112**, the joint estimation part **113**, and the coupling degree estimation part **114**.

The feature amount extraction part **112** extracts the feature amount from the blanked image **301** using the feature amount extraction parameter (S**34**). The joint estimation part **113** obtains the joint estimation result indicating the joint position based on the extracted feature amount using the joint estimation parameter (S**35**). The coupling degree estimation part **114** obtains the coupling degree estimation result indicating the coupling degree between the joints based on the extracted feature amount using the coupling degree estimation parameter (S**36**). The skeleton estimation part **121** obtains the estimated skeleton information from the joint estimation result and the coupling degree estimation result (S**37**). Thereafter, the output part **140** displays the skeleton information on the display device (S**38**). The output part **140** may output the skeleton information to an external server.

In addition, it is also possible to use OpenPose as similar processing from S**33** to S**38**.

4. Function/Effect

As described above, in the estimation device **1** according to the first embodiment, after the input part **130** acquires the image **300**, the blank region **311** is added to the image **300**, and the teaching skeleton information **312** of the user input is taught. Thereafter, the data expansion part **103** and the excess/deficiency region correction part **104** create the teaching data **304** until the data amount required for machine learning is obtained. Machine learning is performed using the created teaching data **304** to learn the estimation model.

After learning, the input part **130** acquires a new image **300**, and then the estimated skeleton information is estimated from the blanked image **301** expanded by the blank region **311** using the learned estimation model.

In this way, the estimation device **1** generates the blanked image **301** or the excess/deficiency corrected image **304***a* that adds the blank regions **311** and **314** to the image **300** (first image), in which the second joint is missing, as the second image. The estimation device **1** performs learning using the second image including the blank region as the input of the estimation model, and using the teaching skeleton information including the joint position of the second joint located in the blank region as the output of the estimation model. Accordingly, the estimation device **1** can create the estimation model that can estimate the skeleton

information including the joint position of the second joint from the image **300** in which the second joint is missing. The estimation device **1** learns by expanding the image range to the region where the second joint is considered to be located, and thereby can appropriately infer the joint position of the second joint located in the blank region **311** that has no image information. Therefore, the estimation device **1** can estimate the estimated skeleton information including the joint positions of the first joint and the second joint from the image **300**, in which the second joint is missing, using the learned estimation model.

In the related art, for example, if the neck or shoulder joint position connecting the right and left arms is not estimated (if the image does not include the neck or shoulder joint position), the positions of the joints of the right arm and the left arm cannot be estimated stably and accurately.

The estimation device **1** estimates the joint positions of the right arm and the left arm as well as the joint position of the neck (or shoulder) connecting the right arm and the left arm, even if the joint position of the neck (or shoulder) is not included in the image. Accordingly, the joint positions of the right arm and the left arm can be estimated stably and accurately.

In addition, the input part can input an image considering privacy in which the head, neck, shoulder, etc. are missing, and an image showing the situation on the work desk. By using the above image, it is possible to analyze not only the time change of the skeleton information due to the time change of the subject, but also the time change of the work target on the work desk. By analyzing these at the same time, the work analysis of the subject can be automated.

Modified Example

The joint estimation part **113** and the coupling degree estimation part **114** may be configured in multiple stages. For example, the joint estimation part **113** and the coupling degree estimation part **114** may obtain the joint estimation result and the coupling degree estimation result from the feature amount, and then perform the estimation again using the joint estimation result and the coupling degree estimation result. In this case, the joint estimation part **113** outputs the first joint estimation result to the coupling degree estimation part **114**, and the coupling degree estimation part **114** outputs the first coupling degree estimation result to the joint estimation part **113**. The joint estimation part **113** obtains the second joint estimation result using the feature amount, the first joint estimation result, and the first coupling degree estimation result. The coupling degree estimation part **114** obtains the second coupling degree estimation result using the feature amount, the first joint estimation result, and the first coupling degree estimation result. At this time, the joint estimation part **113** and the coupling degree estimation part **114** use parameters different from those of the first time. Further, the joint estimation part **113** and the coupling degree estimation part **114** may perform the estimation process three or more times. Accordingly, the accuracy of the estimation is improved.

Second Embodiment

Other embodiments of the present invention will be described below with reference to FIG. **7** to FIG. **9**. For convenience of explanation, members having the same functions as those described in the above embodiment will be assigned with the same reference numerals, and the description thereof will not be repeated.

1. Configuration Example

The configuration of a teaching data creation device **2** according to the present embodiment will be described with reference to FIG. **7**. FIG. **7** is a block diagram showing an example of the main configuration of the teaching data creation device **2**.

As shown in FIG. **7**, the teaching data creation device **2** includes a control part **10** that integrates and controls each part of a learning data creation device, and a storage part **20** that stores various data used by the teaching data creation device **2**. The storage part **20** may be a device externally attached to the teaching data creation device **2**.

The control part **10** includes a blank region expansion part **101**, a teaching data creation part **102**, an input part **130**, and a display control part **150**.

The display control part **150** has a function of displaying the state of the teaching data creation device **2** and displaying an image. A display device (not shown) which is a target controlled by the display control part **150** may be a device externally attached to the teaching data creation device **2**.

A user interface of the learning data creation device according to the present embodiment will be described with reference to FIG. **8**. FIG. **8** is an example of the user interface **51** for designating a joint position in the teaching data creation part.

The user interface **51** includes an image display part **501**, a worker list **511**, an add worker button **513**, a joint list **521**, and a coordinate display instruction part **531**. The display of the user interface **51** is controlled by the display control part **150**.

The image display part **501** is a region for displaying the blanked image **301** according to the instruction of the display control part **150**. In addition, an edited joint position **541**, a definite joint position **542**, and coupling information **543** input by the user input are displayed. The edited joint position **541** and the definite joint position **542** are displayed differently from each other so that they can be identified. The coupling information **543** is a display representing the coupling between the joints according to the coupling relationship of the joints described above. The coupling information **543** is indicated by an arrow in FIG. **8**, but not limited thereto, and the coupling information **543** may be a line segment.

The worker list **511** is a list of workers included in the blanked image **301**. If the blanked image **301** includes only one worker, only "worker 1" is used. The worker that is being set in the worker list **511** may be highlighted as an edited worker **512**.

The joint list **521** is a list of joints that have to be set for the worker. There are nine joints to be set, which are the neck, right shoulder, right elbow, right hand, left shoulder, left elbow, left hand, right hip, and left hip, but not limited thereto, and the head and legs can also be set. The joint that is being set (corresponding to the edited joint position **541**) in the joint list may be highlighted as an edited joint **522**.

The coordinate display instruction part **531** indicates the pixel coordinates that are being set of the edited joint **522**, and includes an X coordinate display instruction part **532** for the X coordinate and a Y coordinate display instruction part **533** for the Y coordinate. In addition to displaying the pixels currently being set for both the X and Y coordinates, user input is also accepted. When the coordinates are changed by

the user input, the display position of the edited joint position **541** is also changed by the display control part **150**.

When changing the coordinates of the edited joint **522** by the input part **130** and the coordinate display instruction part **531**, the user may designate the coordinates that enter the blank region **311** as the coordinates.

2. Operation Example

The operation of the teaching data creation device **2** according to the present embodiment will be described with reference to FIG. **9**. FIG. **9** is an operation flowchart of the teaching data creation device **2**.

The input part **130** acquires the image **300** and outputs the image **300** to the blank region expansion part **101** (S**41**). The blank region expansion part **101** adds the blank region **311** adjacent to the side of the input image **300** and creates the blanked image **301**. The blank region expansion part **101** outputs the blanked image **301** to the teaching data creation part **102** and the display control part **150** (S**42**).

The display control part **150** causes the display device to display the user interface **51**. The display control part **150** displays the blanked image **301** on the image display part **501** (S**43**). The input part **130** receives input from the user via a mouse, keyboard, touch panel, or the like. For example, the input part **130** receives addition of a worker by the add worker button **513**, selection of a worker in the worker list **511**, selection of the edited joint in the joint list **521**, and designation of the edited joint position in the coordinate display instruction part **531** or the image display part **501** (S**44**). At this time, the input part **130** receives not only designation of the joint position of the joint located in the image **300** but also designation of the joint position of the joint located in the blank region **311**. The input part **130** outputs the input information of the worker, joint, and joint position to the teaching data creation part **102** in association with each other.

The teaching data creation part **102** changes the display of the display control part **150** based on the user input. Further, the teaching data creation part **102** generates the teaching skeleton information **312** including information of one or more workers, a plurality of joints, and a plurality of joint positions. The plurality of joints include a first joint located in the region of image **300** and a second joint located in the blank region **311**. The teaching data creation part **102** creates the skeleton-containing data **302** by associating the teaching skeleton information **312** with the blanked image **301** (S**45**).

The teaching data creation part **102** stores the skeleton-containing data **302** in the teaching data storage part **201**.

3. Function/Effect

As described above, the teaching data creation device **2** according to the second embodiment expands the blank region **311** after the input part **130** inputs the image **300**, and displays the blanked image **301** on the user interface **51**. The teaching data creation device **2** can create the teaching skeleton information **312** corresponding to the blanked image **301** by receiving input of the joint position of the joint corresponding to the blank region **311** from the user.

The joint positions constituting the teaching skeleton information may be set in the blank region **311**. Accordingly, an image considering privacy in which the head, neck, shoulder, etc. are missing can be input in the input part, and the teaching skeleton information **312**, which is the data for learning used in the first embodiment, can be created.

Third Embodiment

Yet other embodiments of the present invention will be described below with reference to FIG. **10** and FIG. **11**. For convenience of explanation, members having the same functions as those described in the above embodiment will be assigned with the same reference numerals, and the description thereof will not be repeated.

An example of an input image according to the present embodiment will be described with reference to FIG. **10** and FIG. **11**. FIG. **10** is a schematic diagram of an image of the worker taken from above. FIG. **11** is a schematic diagram of an image of the worker taken from a side.

(Image Taken from Above)

As shown in FIG. **10**, by photographing from above, it is possible to take the image **300***a* that allows the situation on the work desk to be easily grasped without capturing the face of the worker. Therefore, by photographing from above, it is possible to obtain an image suitable for work analysis while protecting privacy.

The image **300***a* includes a worker **601**, a work desk **602**, and a work target **603**. Further, the blank regions **311***a*, **311***b*, **311***c*, and **311***d* are expanded adjacent to the four sides of the image **300***a*. In FIG. **10**, the blank regions are set to be adjacent to all the four sides, but the present invention is not limited thereto, and the blank region may be set to be in contact with any one or more sides.

The worker **601** is a worker to be subjected to work analysis. Elements related to privacy, such as the face of the worker, may not be included in the image. The work desk **602** is a space where the worker works. The work desk **602** may be not only a work desk with a single shelf but also a desk with multiple shelves. The work target **603** is a target for the worker to work on. A marker or the like may be added to the work desk **602** or the work target **603** for work analysis.

As shown in FIG. **10**, by expanding the blank region **311***a* on the upper part of the image **300***a*, the skeleton information can be estimated without capturing the face of the worker or the like. By expanding the blank region **311***b* on the right side of the image **300***a*, the skeleton information can be estimated even when the worker moves to the left side (right side in the image) or reaches the hand for the work target in the space outside the image **300***a*. By expanding the blank region **311***c* on the lower side of the image **300***a*, the skeleton information can be estimated even when the worker reaches the hand for the work target outside the image **300***a*. By expanding the blank region **311***d* on the left side of the image **300***a*, the skeleton information can be estimated even when the worker moves to the right side (left side in the image) or reaches the hand for the work target in the space outside the image **300***a*.

Thus, by photographing from above, it is possible to estimate the skeleton information while protecting privacy, and two-dimensional work analysis on the work desk can be easily performed. Further, by adding a plurality of blank regions to be adjacent to a plurality of sides of the image **300***a*, the skeleton information can be estimated even when the worker moves outside the image **300***a*.

(Image Taken from the Side)

As shown in FIG. **11**, by photographing from the side, it is possible to take the image **300***b* that allows the situation of the multi-tiered workbench to be easily grasped without capturing the face of the worker. Therefore, by photographing from the side, it is possible to obtain an image suitable for work analysis while protecting privacy.

The image **300***b* includes a worker **601**, a work desk **602**, a work target **603**, and a mask region **604**. Further, the blank regions **311***e*, **311***f*, **311***g*, and **311***h* are expanded adjacent to the four sides of the image **300***a*. In FIG. **11**, the blank regions are set to be adjacent to all the four sides, but the present invention is not limited thereto, and the blank region may be set to be in contact with any one or more sides.

The mask region **604** may be set when an element that invades privacy, such as the face of the worker, will be captured due to the installation position and installation direction of the camera. The mask region **604** is filled with the same single color as the blank region **311**. Furthermore, the mask region **604** may be set at an arbitrary position in contact with the blank region and with an arbitrary size.

As shown in FIG. **11**, by expanding the blank region **311***e* on the upper part of the image **300***b*, the skeleton information can be estimated even when parts or tools are disposed on multiple shelves or when they are disposed on the outer upper part of the image **300***b*. By expanding the blank region **311***f* on the right side of the image **300***b*, it is possible to estimate the skeleton information when the hand is reached for the work target installed in the back as seen from the worker of the workbench. By expanding the blank region **311***g* on the lower side of the image **300***b*, it is possible to estimate the skeleton information when the hand is reached for the work target installed on the lower side of the workbench. By expanding the blank region on the left side of the image **300***b*, the skeleton information can be estimated without capturing the face of the worker or the like.

Thus, by photographing from the side, it is possible to estimate the skeleton information while protecting privacy, and the work analysis on the three-dimensional work desk can be easily performed.

The photographing angle is not necessarily from above or from a side, and it is also possible to take an image from the obliquely upper side behind the worker. In this case, it is possible to simultaneously perform two-dimensional work analysis by photographing from above and three-dimensional work analysis by photographing from the side.

[Example of Implementation by Software]

The control blocks of the estimation device **1** and the teaching data creation device **2** (particularly, the blank region expansion part **101**, the teaching data creation part **102**, the data expansion part **103**, the excess/deficiency region correction part **104**, the estimation model acquisition part **111**, the feature amount extraction part **112**, the joint estimation part **113**, the coupling degree estimation part **114**, the skeleton estimation part **121**, the estimation model learning part **122**, the input part **130**, the output part **140**, and the display control part **150** in the control part **10**) may be realized by a logic circuit (hardware) formed in an integrated circuit (IC chip) or the like, or may be realized by software.

In the latter case, the estimation device **1** and the teaching data creation device **2** include a computer that executes commands of a program which is software for realizing each function. The computer includes, for example, one or more processors and a computer-readable recording medium that stores the program. Then, in the computer, the processor reads the program from the recording medium and executes the program, thereby achieving the object of the present invention. For example, a CPU (Central Processing Unit) can be used as the processor. A "non-temporary tangible medium" such as a ROM (Read Only Memory), a tape, a disk, a card, a semiconductor memory, and a programmable logic circuit can be used as the above recording medium. Further, a RAM (Random Access Memory) may be further provided for developing the above program. In addition, the above program may be supplied to the computer via any transmission medium (communication network, broadcast wave, etc.) capable of transmitting the program. One aspect of the present invention can also be realized in the form of a data signal embedded in a carrier wave, in which the above program is embodied by electronic transmission.

[Summary]

In order to solve the above problem, an estimation device according to one aspect of the present invention includes an image acquisition part acquiring a first image that includes a first joint and does not include a second joint of a subject; a blank region expansion part generating a second image obtained by expanding the first image with a blank region; and an estimation part estimating skeleton information including a joint position of the second joint located in the blank region using the second image and a learned estimation model.

According to the above configuration, by adding the blank region to the first image in which the second joint is missing, the skeleton information including the joint position of the second joint located in the blank region can be stably estimated.

The blank region expansion part may set the blank region adjacent to one side of the first image.

According to the above configuration, the joint position of the second joint of the subject existing at a position beyond one side of the first image can be estimated.

The second joint may include a neck joint.

According to the above configuration, the first image can be, for example, an image in which the shoulder, elbow, hand, and hip are shown, but the neck is not shown. Therefore, the skeleton information including the neck can be estimated stably and accurately using the first image in which the face of the subject is not shown.

The image acquisition part may acquire the first image taken from above.

According to the above configuration, by using the image taken from above, for example, the face of the subject can be prevented from being shown, and work analysis can be performed using the work target on the work desk and the skeleton information of the subject (worker) together.

In order to solve the above problem, a learning device according to one aspect of the present invention includes an image acquisition part acquiring a first image that includes a first joint and does not include a second joint of a subject; a blank region expansion part generating a second image obtained by expanding the first image with a blank region; a teaching data storage part storing teaching data including skeleton information, which includes the second joint located in the blank region, and the second image; and a learning part learning an estimation model of skeleton information from the skeleton information and the second image using the teaching data.

According to the above configuration, by adding the blank region to the first image in which the second joint is missing, and including the second joint located on the blank region in the teaching data, the skeleton information having the second joint in the blank region can be learned.

The blank region expansion part may set the blank region adjacent to one side of the first image.

The second joint may include a neck joint.

The learning device may include a data expansion part performing image processing of geometric deformation on the second image to generate a third image; and a deficiency region correction part correcting a deficiency pixel region in

a region corresponding to the second image in the third image with a blank region as a new second image for learning.

According to the above configuration, a plurality of pieces of teaching data can be created even from a small number of images, and the learning can be performed efficiently.

The image acquisition part may acquire the first image taken from above.

According to the above configuration, by using the image taken from above, the estimation model can be learned from the work target on the work desk and the skeleton information of the subject (worker).

In order to solve the above problem, a teaching data creation device according to one aspect of the present invention includes an image acquisition part acquiring a first image that includes a first joint and does not include a second joint of a subject; a blank region expansion part generating a second image obtained by expanding the first image with a blank region; a display control part displaying the second image; an input part receiving input of a joint position of the second joint with respect to the blank region in the second image from a user; and a teaching data creation part creating teaching data in which skeleton information including joint positions of the first joint and the second joint is associated with the second image.

According to the above configuration, by adding the blank region to the first image in which the second joint is missing, the teaching data including the joint position of the second joint located in the blank region can be created.

The blank region expansion part may set the blank region adjacent to one side of the first image.

The second joint may include a neck joint.

An estimation method according to one aspect of the present invention includes an image acquisition step of acquiring a first image that includes a first joint and does not include a second joint of a subject; a blank region expansion step of generating a second image obtained by expanding the first image with a blank region; and an estimation step of estimating skeleton information including a joint position of the second joint located in the blank region using the second image and a learned estimation model.

A learning method according to one aspect of the present invention includes an image acquisition step of acquiring a first image that includes a first joint and does not includes a second joint of a subject; a blank region expansion step of generating a second image obtained by expanding the first image with a blank region; a teaching data acquisition step of acquiring teaching data including skeleton information, which includes the second joint located in the blank region, and the second image; and a learning step of learning an estimation model of skeleton information from the skeleton information and the second image using the teaching data.

A teaching data creation method according to one aspect of the present invention includes an image acquisition step of acquiring a first image that includes a first joint and does not include a second joint of a subject; a blank region expansion step of generating a second image obtained by expanding the first image with a blank region; a display control step of displaying the second image; an input step of receiving input of a joint position of the second joint with respect to the blank region in the second image from a user; and a teaching data creation step of creating teaching data in which skeleton information including joint positions of the first joint and the second joint is associated with the second image.

The estimation device according to each aspect of the present invention may be realized by a computer, and in this case, an estimation program that realizes the estimation device in the computer by operating the computer as each part (software element) included in the estimation device, and a computer-readable recording medium recording the same also fall within the scope of the present invention.

The learning device according to each aspect of the present invention may be realized by a computer, and in this case, a learning program that realizes the learning device in the computer by operating the computer as each part (software element) included in the learning device, and a computer-readable recording medium recording the same also fall within the scope of the present invention.

The teaching data creation device according to each aspect of the present invention may be realized by a computer, and in this case, a teaching data creation program that realizes the teaching data creation device in the computer by operating the computer as each part (software element) included in the teaching data creation device, and a computer-readable recording medium recording the same also fall within the scope of the present invention.

[Additional Notes]

The present invention is not limited to the above-described embodiments, and various modifications can be made within the scope of the claims. The technical scope of the present invention also includes embodiments obtained by appropriately combining the technical means disclosed in different embodiments.

What is claimed is:

1. An estimation device, comprising:

a first processor, configured to:

acquire a first image that includes a first joint and does not include a second joint of a subject;

add a blank region adjacent to the first image to generate a second image; and

estimate skeleton information including a joint position of the second joint located in the blank region using the second image and a learned estimation model.

2. The estimation device according to claim **1**, wherein the first processor sets the blank region adjacent to one side of the first image.

3. The estimation device according to claim **1**, wherein the second joint includes a neck joint.

4. The estimation device according to claim **1**, wherein the first processor acquires the first image taken from above.

5. A learning device, comprising:

a memory; and

a second processor, configured to:

acquire a first image that includes a first joint and does not include a second joint of a subject;

add a blank region adjacent to the first image to generate a second image;

store teaching data including skeleton information, which includes the second joint located in the blank region, and the second image in the memory; and

learn an estimation model of skeleton information from the skeleton information and the second image using the teaching data.

6. The learning device according to claim **5**, wherein the second processor sets the blank region adjacent to one side of the first image.

7. The learning device according to claim **5**, wherein the second joint includes a neck joint.

8. The learning device according to claim **5**, wherein the second processor is further configured to:

perform image processing of geometric deformation on the second image to generate a third image; and

correct a deficiency pixel region in the third image with another blank region to generate a new second image for learning, wherein the deficiency pixel region in the third image corresponds to a region in the second image.

9. The learning device according to claim **5**, wherein the the second processor acquires the first image taken from above.

10. A teaching data creation device, comprising:

a display; and

a third processor, configured to:

acquire a first image that includes a first joint and does not include a second joint of a subject;

add a blank region adjacent to the first image to generate a second image;

display the second image on the display;

receive input of a joint position of the second joint with respect to the blank region in the second image from a user; and

create teaching data in which skeleton information including joint positions of the first joint and the second joint is associated with the second image.

11. The teaching data creation device according to claim **10**, wherein third processor sets the blank region adjacent to one side of the first image.

12. The teaching data creation device according to claim **10**, wherein the second joint includes a neck joint.

13. An estimation method, comprising:

acquiring a first image that includes a first joint and does not include a second joint of a subject;

adding a blank region adjacent to the first image to generate a second image; and

estimating skeleton information including a joint position of the second joint located in the blank region using the second image and a learned estimation model.

14. A learning method, comprising:

acquiring a first image that includes a first joint and does not includes a second joint of a subject;

adding a blank region adjacent to the first image to generate a second image;

storing teaching data including skeleton information, which includes the second joint located in the blank region, and the second image, in a memory; and

learning an estimation model of skeleton information from the skeleton information and the second image using the teaching data.

15. A teaching data creation method, comprising:

acquiring a first image that includes a first joint and does not include a second joint of a subject;

adding a blank region adjacent to the first image to generate a second image;

displaying the second image on a display;

receiving input of a joint position of the second joint with respect to the blank region in the second image from a user; and

creating teaching data in which skeleton information including joint positions of the first joint and the second joint is associated with the second image.

16. A non-transitory computer-readable recording medium, recording an estimation program for operating a computer as the estimation device according to claim **1**.

17. A non-transitory computer-readable recording medium, recording a learning program for operating a computer as the learning device according to claim **5**.

18. A non-transitory computer-readable recording medium, recording a teaching data creation program for operating a computer as the teaching data creation device according to claim **10**.

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