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(54) **KEY POINT CORRECTION SYSTEM, KEY POINT CORRECTION METHOD, AND NONTRANSITORY COMPUTER READABLE MEDIUM**

(71) Applicant: **TOYOTA JIDOSHA KABUSHIKI KAISHA**, Toyota -shi Aichi-ken (JP)

(72) Inventor: **Yusuke NAKANO**, Nagoya-shi Aichi-ken (JP)

(73) Assignee: **TOYOTA JIDOSHA KABUSHIKI KAISHA**, Toyota -shi Aichi-ken (JP)

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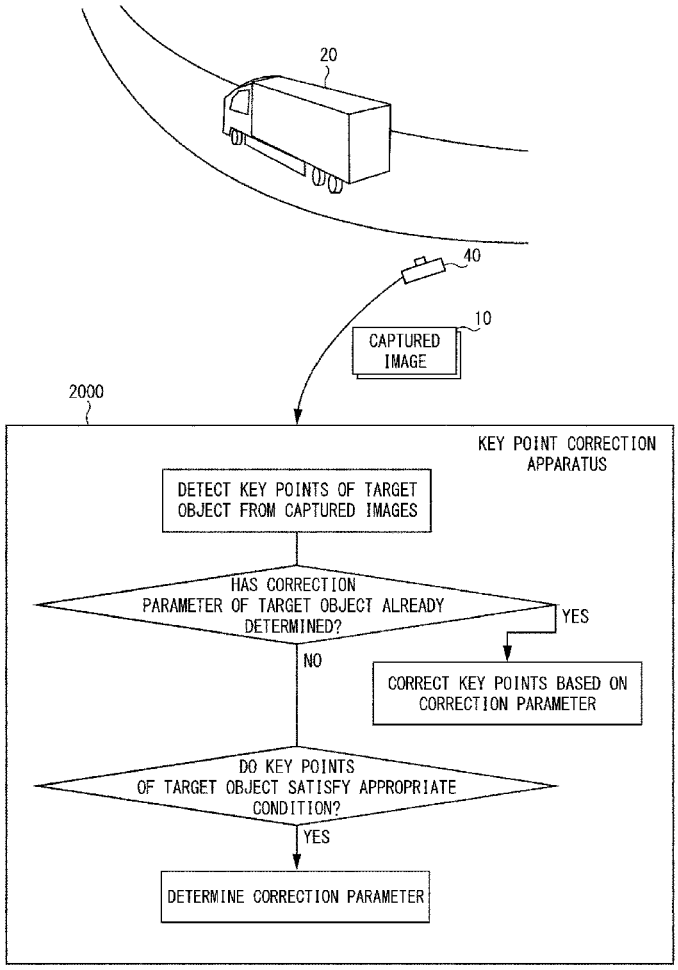
(57) **ABSTRACT**

A key point correction apparatus detects a plurality of key points of a target object from each of a plurality of captured images. The key point correction apparatus decides whether or not a plurality of key points of the target object detected from the captured image satisfy an appropriacy condition. When the key points of the target object satisfy the appropriacy condition, the key point correction apparatus determines a correction parameter regarding the target object using the key points. When a correction parameter has been determined for the target object detected from the captured image, the key point correction apparatus corrects the key points of the target object using a correction parameter.



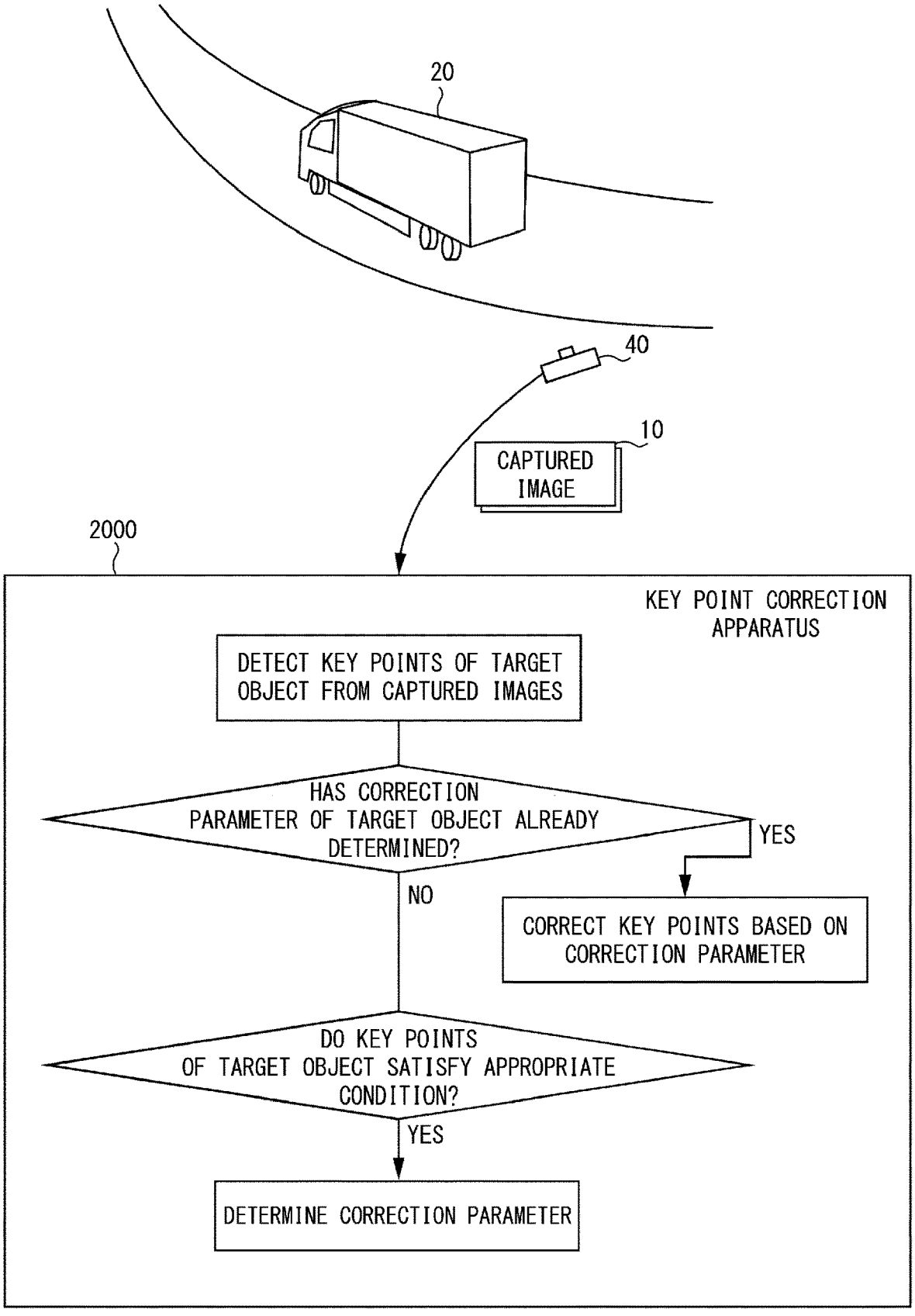

20
40
10
CAPTURED IMAGE
2000
KEY POINT CORRECTION APPARATUS
DETECT KEY POINTS OF TARGET OBJECT FROM CAPTURED IMAGES
HAS CORRECTION PARAMETER OF TARGET OBJECT ALREADY DETERMINED?
YES
NO
CORRECT KEY POINTS BASED ON CORRECTION PARAMETER
DO KEY POINTS OF TARGET OBJECT SATISFY APPROPRIATE CONDITION?
YES
DETERMINE CORRECTION PARAMETER

Fig. 1

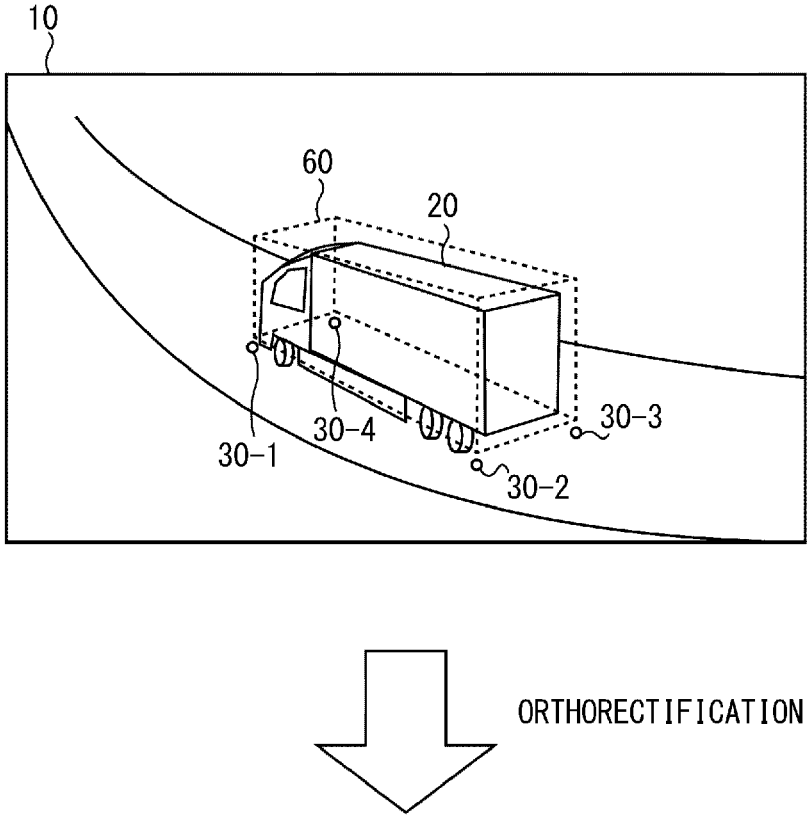

10
60
20
30-1
30-4
30-3
30-2
ORTHORECTIFICATION
50
80-4
80-1
80-3
80-2

Fig. 2

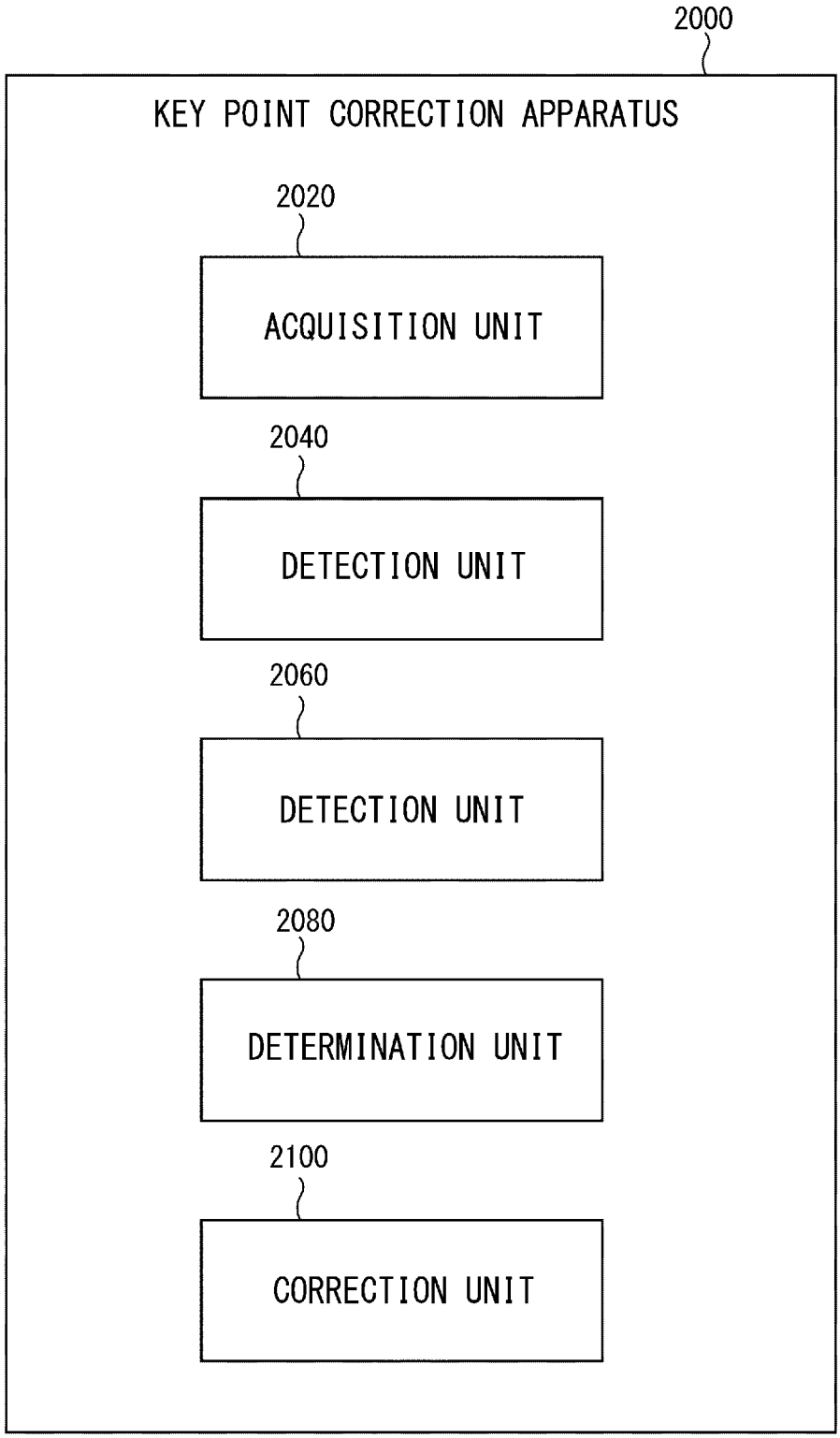

2000
KEY POINT CORRECTION APPARATUS
2020
ACQUISITION UNIT
2040
DETECTION UNIT
2060
DETECTION UNIT
2080
DETERMINATION UNIT
2100
CORRECTION UNIT

Fig. 3

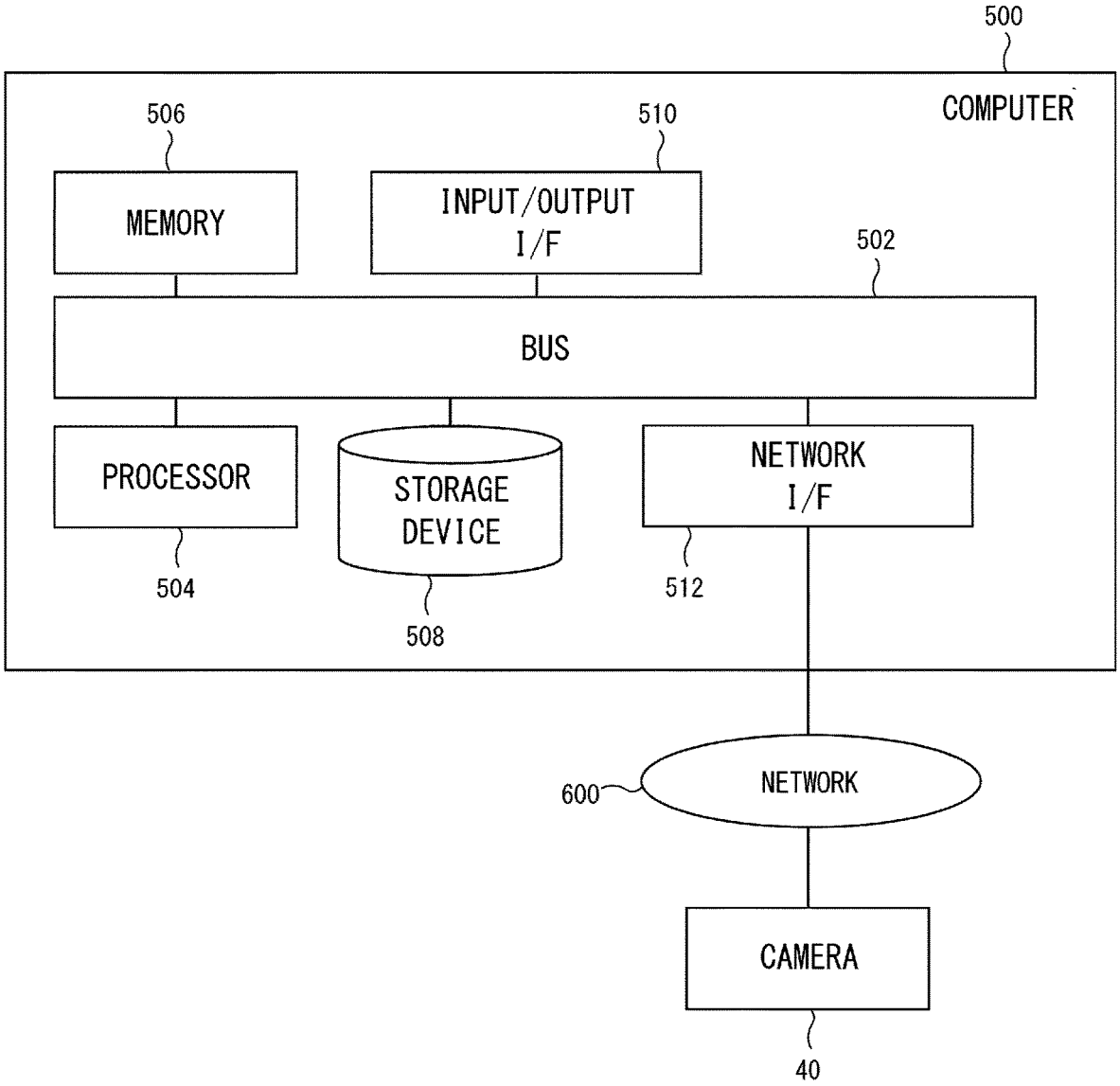

500
COMPUTER
506
MEMORY
510
INPUT/OUTPUT I/F
502
BUS
PROCESSOR
504
STORAGE DEVICE
508
NETWORK I/F
512
600
NETWORK
CAMERA
40

Fig. 4

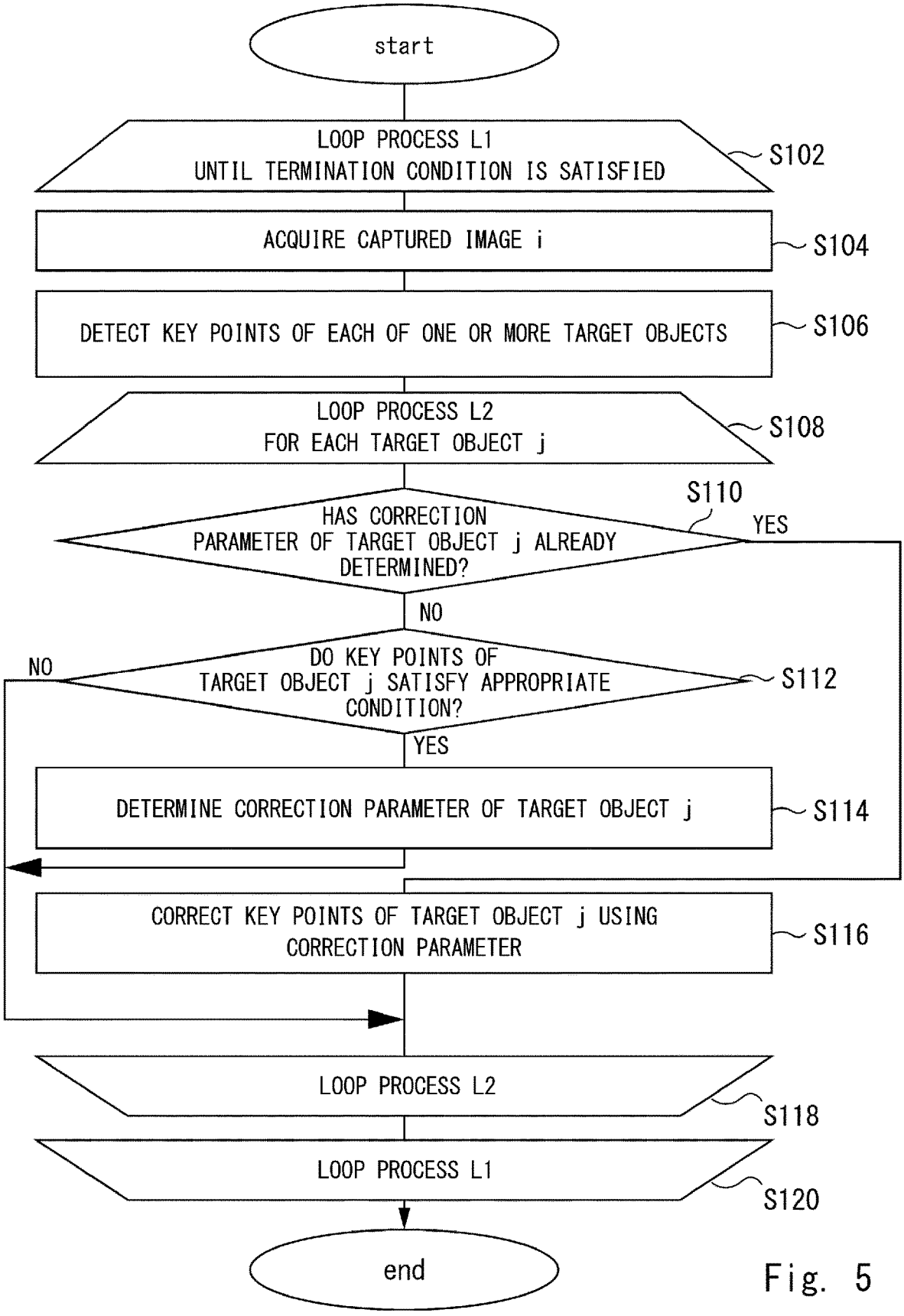

start
LOOP PROCESS L1
UNTIL TERMINATION CONDITION IS SATISFIED
S102
ACQUIRE CAPTURED IMAGE i
S104
DETECT KEY POINTS OF EACH OF ONE OR MORE TARGET OBJECTS
S106
LOOP PROCESS L2
FOR EACH TARGET OBJECT j
S108
S110
HAS CORRECTION PARAMETER OF TARGET OBJECT j ALREADY DETERMINED?
YES
NO
NO
DO KEY POINTS OF TARGET OBJECT j SATISFY APPROPRIATE CONDITION?
S112
YES
DETERMINE CORRECTION PARAMETER OF TARGET OBJECT j
S114
CORRECT KEY POINTS OF TARGET OBJECT j USING CORRECTION PARAMETER
S116
LOOP PROCESS L2
S118
LOOP PROCESS L1
S120
end

Fig. 5

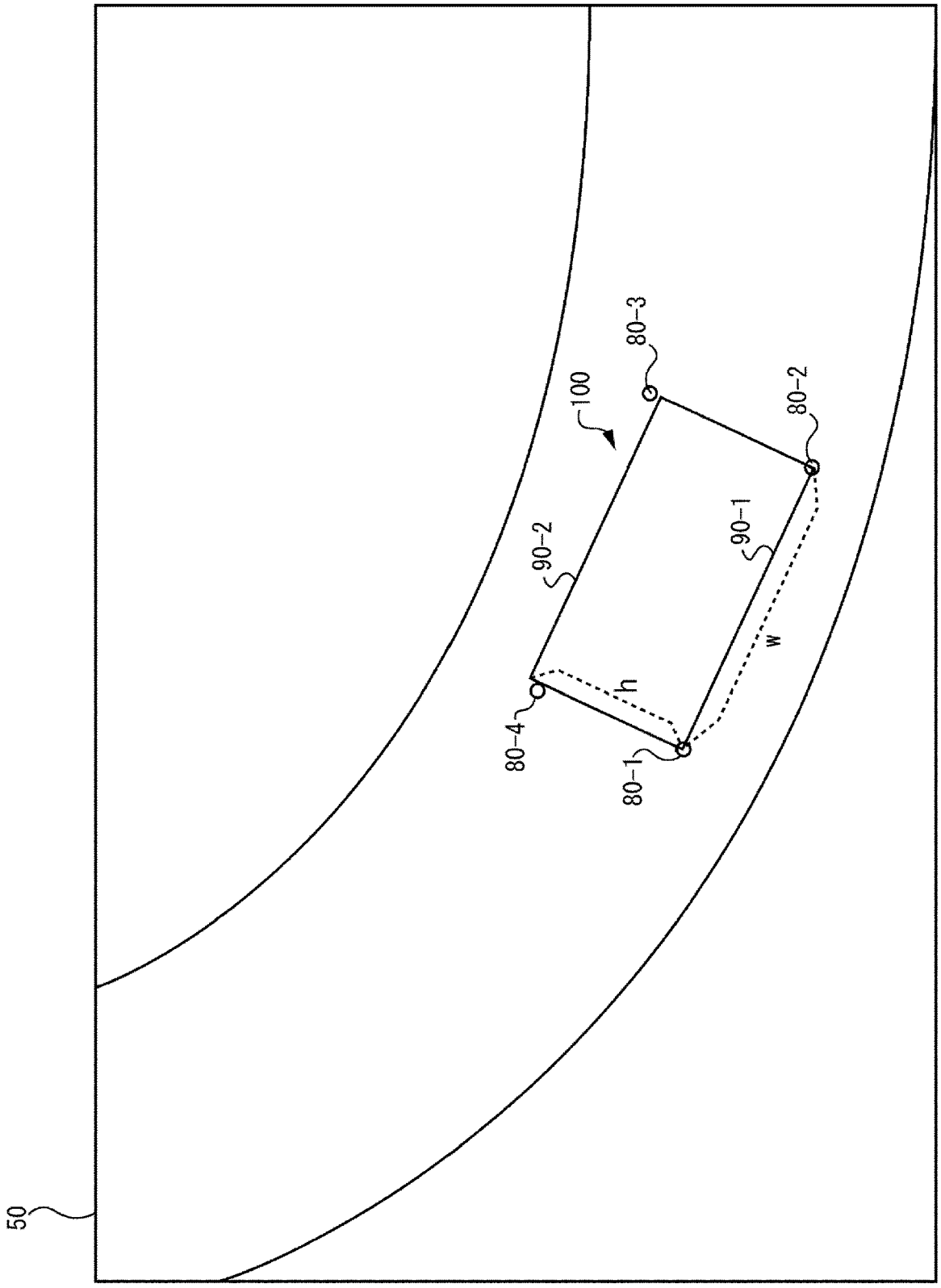



Fig. 6

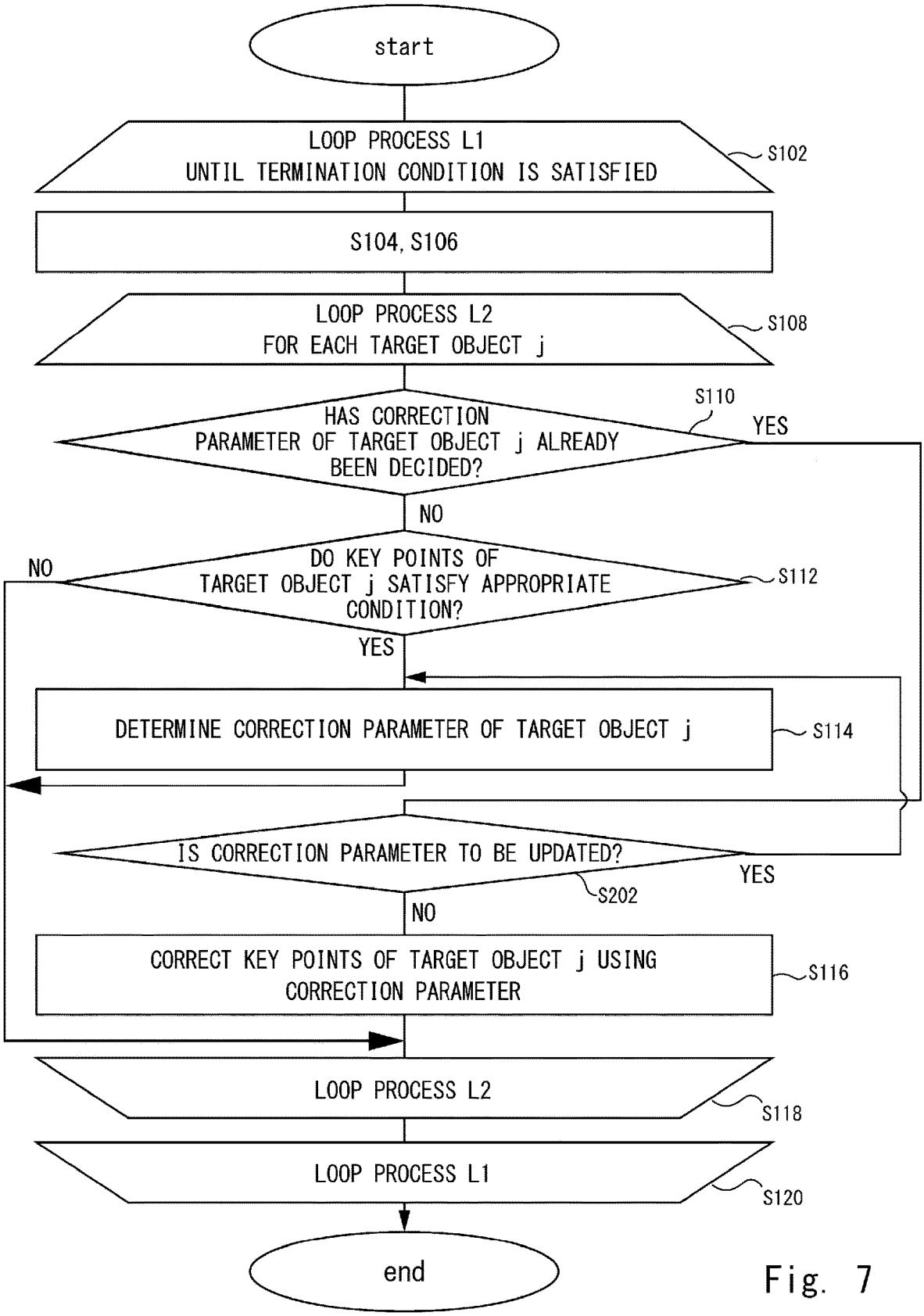
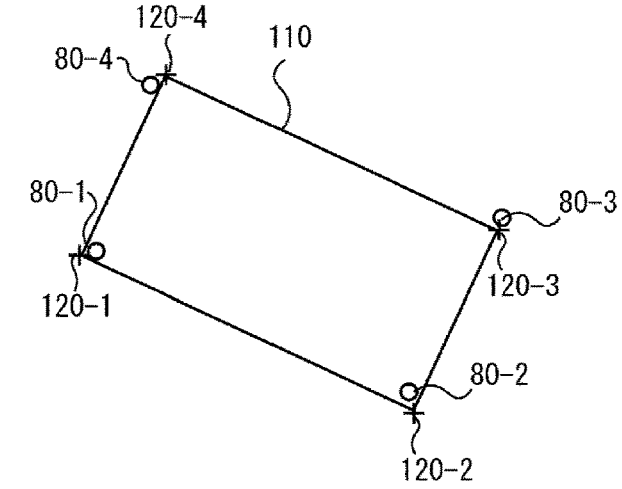
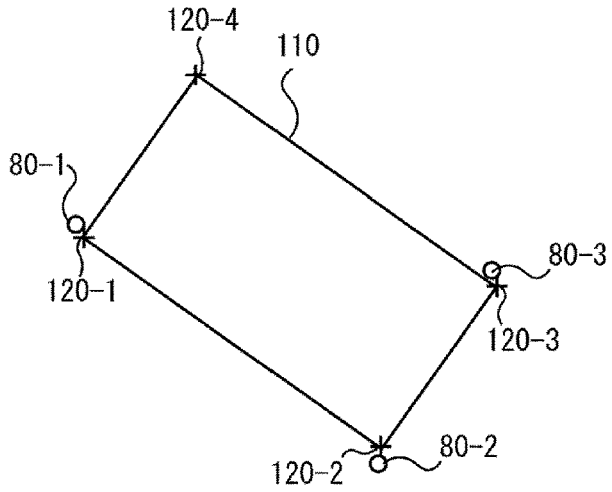

start
LOOP PROCESS L1
UNTIL TERMINATION CONDITION IS SATISFIED
S102
S104, S106
LOOP PROCESS L2
FOR EACH TARGET OBJECT j
S108
HAS CORRECTION PARAMETER OF TARGET OBJECT j ALREADY BEEN DECIDED?
S110
YES
NO
DO KEY POINTS OF TARGET OBJECT j SATISFY APPROPRIATE CONDITION?
S112
NO
YES
DETERMINE CORRECTION PARAMETER OF TARGET OBJECT j
S114
IS CORRECTION PARAMETER TO BE UPDATED?
S202
YES
NO
CORRECT KEY POINTS OF TARGET OBJECT j USING CORRECTION PARAMETER
S116
LOOP PROCESS L2
S118
LOOP PROCESS L1
S120
end

Fig. 7


120-4
110
80-4
80-1
80-3
120-1
120-3
80-2
120-2


120-4
110
80-1
80-3
120-1
120-3
120-2
80-2

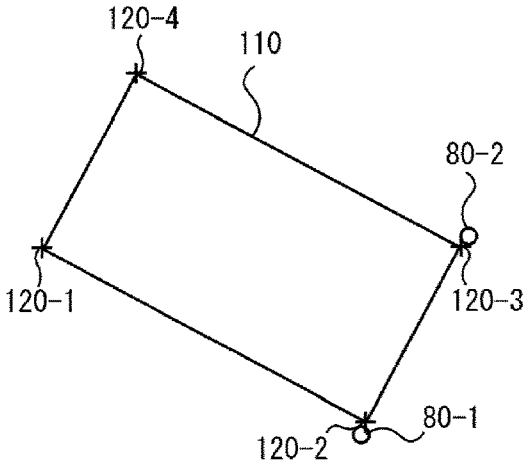

120-4
110
80-2
120-1
120-3
80-1
120-2

Fig. 8

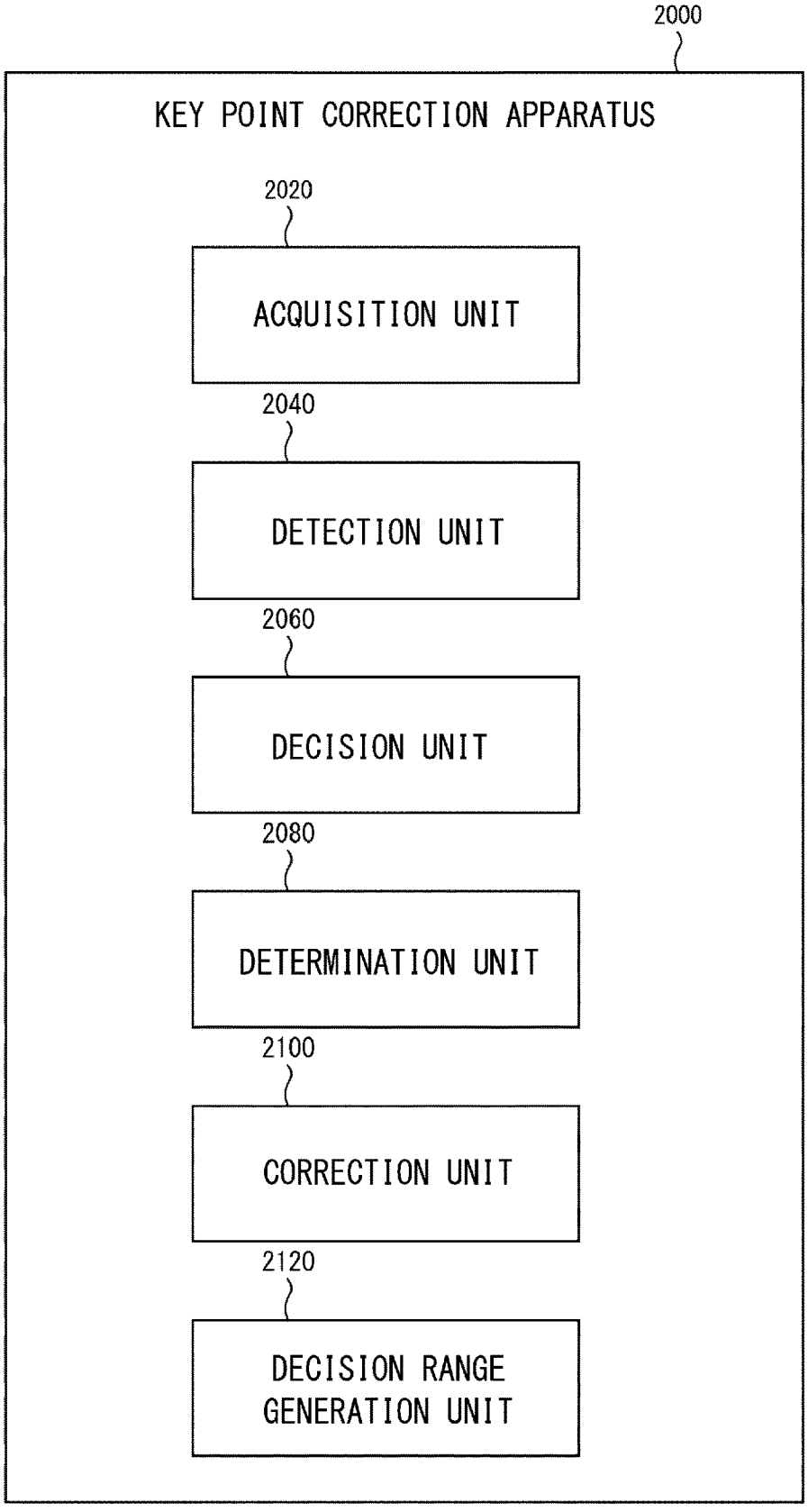

2000
KEY POINT CORRECTION APPARATUS
2020
ACQUISITION UNIT
2040
DETECTION UNIT
2060
DECISION UNIT
2080
DETERMINATION UNIT
2100
CORRECTION UNIT
2120
DECISION RANGE GENERATION UNIT

Fig. 9

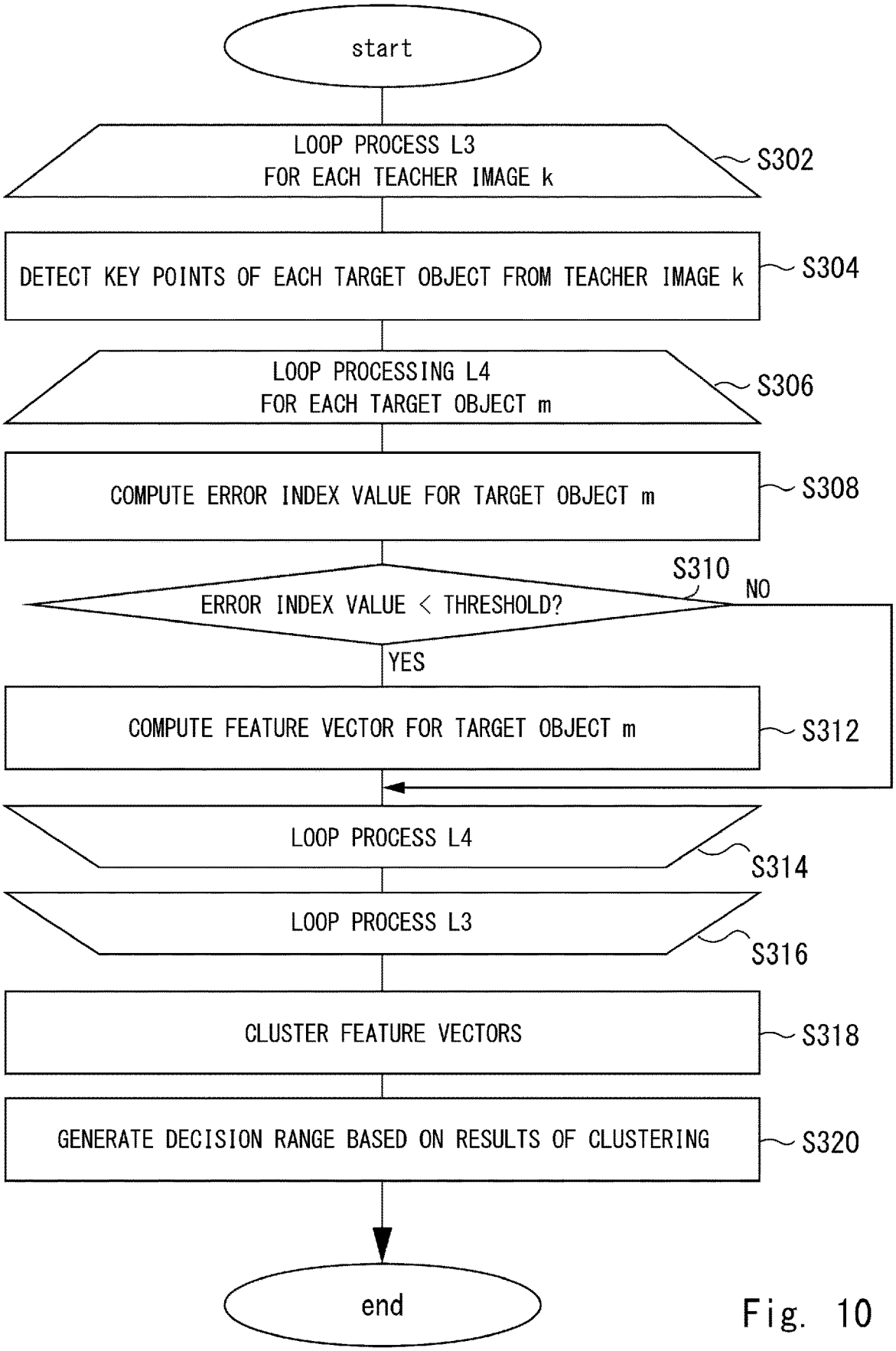

start
LOOP PROCESS L3
FOR EACH TEACHER IMAGE k
S302
DETECT KEY POINTS OF EACH TARGET OBJECT FROM TEACHER IMAGE k
S304
LOOP PROCESSING L4
FOR EACH TARGET OBJECT m
S306
COMPUTE ERROR INDEX VALUE FOR TARGET OBJECT m
S308
S310
ERROR INDEX VALUE < THRESHOLD?
NO
YES
COMPUTE FEATURE VECTOR FOR TARGET OBJECT m
S312
LOOP PROCESS L4
S314
LOOP PROCESS L3
S316
CLUSTER FEATURE VECTORS
S318
GENERATE DECISION RANGE BASED ON RESULTS OF CLUSTERING
S320
end

Fig. 10

# KEY POINT CORRECTION SYSTEM, KEY POINT CORRECTION METHOD, AND NONTRANSITORY COMPUTER READABLE MEDIUM

## CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is based upon and claims the benefit of priority from Japanese patent application No. 2021-185000, filed on Nov. 12, 2021, the disclosure of which is incorporated herein in its entirety by reference.

## BACKGROUND

[0002] The present disclosure relates to a technique for detecting key points of a moving object included in a captured image.

[0003] Techniques for detecting key points of a moving object such as a vehicle or a person in an image by analyzing a captured image obtained by photographing the moving object have been developed. For example, Japanese Unexamined Patent Application Publication No. 2010-039617 discloses a technique for detecting key points of a moving object from a plurality of captured images generated at timings different from each other and stably tracking the moving object that is partially deformed using the detected key points.

## SUMMARY

[0004] Japanese Unexamined Patent Application Publication No. 2010-039617 does not mention about an accuracy of key points. The present disclosure provides a technique for improving the accuracy of key points of a moving object detected from a captured image.

[0005] A key point correction system according to the present disclosure includes: at least one memory storing instructions; and at least one processor. The at least one processor is configured to execute the instructions to: acquire a plurality of captured images; detect a plurality of key points of a moving object from each of the captured images; decide whether or not the plurality of key points of the moving object detected from the captured images satisfy a predetermined appropriacy condition; determine, when the plurality of key points of the moving object satisfy the appropriacy condition, a correction parameter to be used to correct the plurality of key points detected for the moving object using the plurality of key points; and correct, when the correction parameter has been determined for the moving object regarding which the plurality of key points are detected from the captured image, the plurality of key points by using the correction parameter.

[0006] A key point correction method according to the present disclosure is executed by a computer. This control method includes: acquiring a plurality of captured images; detecting a plurality of key points of a moving object from each of the captured images; deciding whether or not the plurality of key points of the moving object detected from the captured images satisfy a predetermined appropriacy condition; determining, when the plurality of key points of the moving object satisfy the appropriacy condition, a correction parameter to be used to correct the plurality of key points detected for the moving object using the plurality of key points; and correcting, when the correction parameter has been determined for the moving object regarding which the plurality of key points are detected from the captured image, the plurality of key points by using the correction parameter.

[0007] A non-transitory computer readable medium according to the present disclosure stores a program for causing a computer to execute a key point correction method according to the present disclosure.

[0008] According to the present disclosure, a technique for improving the accuracy of key points of a moving object detected from a captured image is provided.

[0009] The above and other objects, features and advantages of the present disclosure will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus are not to be considered as limiting the present disclosure.

## BRIEF DESCRIPTION OF DRAWINGS

[0010] FIG. **1** is a diagram illustrating an overview of operations of a key point correction apparatus according to a first embodiment;

[0011] FIG. **2** is a diagram illustrating key points of a target object;

[0012] FIG. **3** is a block diagram illustrating a functional configuration of the key point correction apparatus according to the first embodiment;

[0013] FIG. **4** is a block diagram illustrating a hardware configuration of a computer that implements the key point correction apparatus;

[0014] FIG. **5** is a flowchart illustrating a flow of process executed by the key point correction apparatus according to the first embodiment;

[0015] FIG. **6** is a diagram illustrating a method for determining a rectangular area representing the target object;

[0016] FIG. **7** is a flowchart illustrating a flow of process of the key point correction apparatus having a function of updating a correction parameter;

[0017] FIG. **8** is a diagram illustrating a method for correcting key point correspondence points using a correction rectangle;

[0018] FIG. **9** is a block diagram illustrating a functional configuration of a key point correction apparatus including a decision range generation unit; and

[0019] FIG. **10** is a flowchart illustrating a flow of process of generating a decision range using training images.

## DESCRIPTION OF EMBODIMENTS

[0020] In the following description, with reference to the drawings, embodiments of the present disclosure will be described in detail. Throughout the drawings, the same or corresponding elements are denoted by the same symbols and redundant descriptions will be omitted as necessary for the sake of clarification of the description. Further, unless otherwise explained, values that are defined in advance such as predetermined values or thresholds are stored in advance in a storage unit or the like that is accessible from an apparatus that uses the values. Further, unless otherwise explained, the storage unit is implemented with one or more storage devices of any number.

First Embodiment

<Overview>

**[0021]** FIG. **1** is a diagram illustrating an overview of operations of a key point correction apparatus (system) **2000** according to a first embodiment. FIG. **1** is a diagram for facilitating understanding of the overview of the key point correction apparatus **2000**, and the operations of the key point correction apparatus **2000** are not limited to those shown in FIG. **1**.

**[0022]** The key point correction apparatus **2000** detects key points of a target object **20** from a time series of a plurality of captured images **10** (e.g., a plurality of video frames that form video data). The target object **20** is a moving object of a predetermined kind that is handled as a target of key point detection. The predetermined kind of moving object may include, for example, a vehicle, a person, or a mobile robot. The vehicle may be any one of various kinds of vehicles, such as any automobile (e.g., a bus, a truck, or a passenger car), a motorcycle, or a bicycle. Note that the type of the moving object that the key point correction apparatus **2000** handles as the target object **20** is not limited to one type of moving object and each of a plurality of kinds of moving objects may be handled as the target object **20**. The key point correction apparatus **2000** detects, for example, any kinds of vehicle and persons as target objects **20**.

**[0023]** The captured images **10** are generated by a camera **40** installed so as to be able to photograph the target object **20**. For example, when a vehicle or a person is handled as the target object **20**, the camera **40** is installed in a place from which it can photograph the road. The camera **40** may be a video camera that generates video data or may be a still camera that generates still image data. In the latter case, the camera **40** generates a time series of a plurality of captured images **10** by repeatedly photographing the target object **20**.

**[0024]** The key points of the target object **20** are feature points of the target object **20** detected from the captured images **10**, and can be used to represent the position or the posture of the target object **20**. The key points are, for example, points that are obtained by projecting, onto the road, vertices of a bottom surface of a three-dimensional bounding box that surrounds the target object **20**.

**[0025]** FIG. **2** is a diagram illustrating the key points of the target object **20**. FIG. **2** shows a captured image **10** and an orthoimage **50** obtained by performing orthorectification on the captured image **10**. The orthorectification for obtaining the orthoimage **50** from the captured image **10** can be achieved by using a predetermined homography matrix.

**[0026]** A bounding box **60** is a three-dimensional bounding box that surrounds a target object **20** detected from the captured image **10**. Key points **30-1**, **30-2**, **30-3**, and **30-4**, which are key points of the target object **20**, can be obtained by projecting the respective vertices of the bottom surface of the bounding box **60** onto the road.

**[0027]** Key point correspondence points **80** represent the key points **30** projected onto the orthoimage **50** by orthorectification. A key point correspondence point **80-1**, a key point correspondence point **80-2**, a key point correspondence point **80-3**, and a key point correspondence point **80-4** respectively correspond to the key point **30-1**, the key point **30-2**, the key point **30-3**, and the key point **30-4**.

**[0028]** The key points **30** are not limited to the points obtained by projecting the vertices of the bottom surface of the three-dimensional bounding box of the target object **20** onto the road. For example, the respective vertices of the three-dimensional bounding box of the target object **20** may be handled as the key points **30**.

**[0029]** The key point correction apparatus **2000** detects the key points **30** of the target object **20** included in each of the captured images **10**. If a plurality of target objects **20** are detected from one captured image **10**, the key points **30** are detected for each of these plurality of target objects **20**.

**[0030]** The key point correction apparatus **2000** further decides, for each captured image **10**, whether or not there exists a target object **20**, among the target objects **20** detected from the captured image **10**, whose key points **30** satisfy a predetermined appropriacy condition. The appropriacy condition is a condition that is satisfied when it is highly likely that key points **30** of a target object **20** are detected with a high accuracy from a captured image **10** and when the key points **30** are suitable for deciding a correction parameter of the target object **20** that will be described later. The details of the appropriacy condition will be described later.

**[0031]** When the key points **30** of a target object **20** detected from a captured image **10** satisfy the appropriacy condition, this captured image **10** is referred to as an appropriate image that corresponds to the target object **20**. In other words, the appropriate image that corresponds to a target object **20** is a captured image **10** whose key points **30** detected from the target object **20** satisfy the appropriacy condition.

**[0032]** When it is decided that the key points **30** of the target object **20** detected from the captured image **10** satisfy the appropriacy condition, the key point correction apparatus **2000** determines, for the target object **20** that corresponds to this captured image **10** (appropriate image), a correction parameter that is used to correct the key points **30**. The correction parameter represents a relative positional relation that a plurality of key points **30** detected for the corresponding target object **20** should satisfy. For example, the key point correction apparatus **2000** uses the key point correspondence points **80** on the orthoimage **50** obtained from the appropriate image to determine a rectangular area on the orthoimage **50** that represents the target object **20** corresponding to this appropriate image. Then, the key point correction apparatus **2000** determines a combination of the width and the height of this rectangular area as a correction parameter that corresponds to the target object **20**. The relative positional relation that the key point correspondence points **80** of the target object **20** should satisfy is defined by this correction parameter. Here, the key point correspondence points **80** are points that correspond to the key points **30**. Thus, as a result of the relative positional relation that the key point correspondence points **80** of the target object **20** should satisfy being defined, a relative positional relation that the key points **30** of the target object **20** should satisfy is defined as well.

**[0033]** When the correction parameter is determined for the target object **20** detected from the captured image **10**, the key point correction apparatus **2000** corrects the key points **30** of the target object **20** detected from the captured image **10** using the correction parameter determined for this target object **20**. In other words, when a target object **20** is detected from a captured image **10** that is generated later than an appropriate image of this target object **20**, the key point correction apparatus **2000** corrects the key points **30** of the

target object **20** detected from the captured image **10** using the correction parameter that has been determined for this target object **20**.

Examples of Effects

**[0034]** The key point correction apparatus **2000** detects the key points **30** of the target object **20** from the captured image **10**. The accuracy of the process of detecting the key points **30** from the captured image **10** may vary depending on how the target object **20** is seen in the captured image **10**. For example, In a situation in which the position or the posture of the target object **20** is a position or a posture with which only one side surface of the target object **20** can be captured by the camera **40**, the target object **20** can be captured by the camera **40** only in a plan view, whereby the accuracy of the process of detecting the key points **30** of the target object **20** may be low. On the other hand, when the position or the posture of the target object **20** is a position or a posture with which the upper surface and two side surfaces of the target object **20** can be captured by the camera **40**, this target object **20** can be captured by the camera **40** in a three dimensional way, whereby the accuracy of the process of detecting the key points **30** of the target object **20** may be high.

**[0035]** In view of those situations in which there may be differences in the accuracy of the key points **30**, the key point correction apparatus **2000** uses the key points **30** that are considered to have been detected with high accuracy to correct the other key points **30**. The appropriacy condition is defined in advance in such a way that this condition is satisfied when the key points **30** are considered to have been detected with high accuracy. Then, when the key points **30** of the target object **20** detected from the captured image **10** satisfy the appropriacy condition, the key point correction apparatus **2000** determines the correction parameter of the target object **20** using the key points **30**. According to this procedure, the correction parameter is defined based on the key points **30** that are considered to have been detected with high accuracy. Then, when a target object **20** whose correction parameter has been determined is detected from the captured image **10**, the key point correction apparatus **2000** corrects the key points **30** of this target object **20** using the correction parameter. According to this procedure, based on the key points **30** considered to have been detected with high accuracy, the other key points **30** are corrected. Therefore, by using the key point correction apparatus **2000**, the accuracy of the key points **30** may be improved.

**[0036]** In the following, the key point correction apparatus **2000** according to this example embodiment will be described in further detail.

<Example of Functional Configuration>

**[0037]** FIG. **3** is a block diagram illustrating a functional configuration of the key point correction apparatus **2000** according to the first embodiment. An acquisition unit **2020** acquires a plurality of captured images **10**. A detection unit **2040** detects key points **30** of a target object **20** included in each of the captured images **10**. A decision unit **2060** decides whether or not the key points **30** of the target object **20** detected from the captured images **10** satisfy an appropriacy condition regarding whether to use these key points **30** to decide a correction parameter. When the key points **30** of the target object **20** detected from the captured images **10** satisfy the appropriacy condition, a determination unit **2080** determines the correction parameter regarding the target object **20** using the key points **30**. When the correction parameter that corresponds to the target object **20** detected from the captured images **10** has been determined, a correction unit **2100** corrects the key points **30** of the target object **20** detected from the captured images **10** using the correction parameter that corresponds to the target object **20**.

<Example of Hardware Configuration>

**[0038]** Each functional configuration unit of the key point correction apparatus **2000** may be implemented with hardware (e.g., a hardwired electronic circuit) that implements each functional configuration unit or by a combination of hardware with software (e.g., a combination of an electronic circuit with a program that controls the electronic circuit). Hereinafter, a case in which each functional configuration unit of the key point correction apparatus **2000** is implemented with a combination of hardware with software will be further described.

**[0039]** FIG. **4** is a block diagram illustrating a hardware configuration of a computer **500** that implements the key point correction apparatus **2000**. The computer **500** may be any type of computer. The computer **500** is, for example, a stationary computer such as a Personal Computer (PC) or a server machine. The computer **500** may instead be a portable computer such as a smartphone or a tablet terminal. Note that the computer **500** may be provided inside the camera **40** that generates captured images **10**. The computer **500** may be a special-purpose computer that is designed to implement the key point correction apparatus **2000** or may be a general-purpose computer.

**[0040]** By installing a predetermined application in the computer **500**, for example, each function of the key point correction apparatus **2000** is implemented in the computer **500**. The above application is formed of a program that implements each functional configuration unit of the key point correction apparatus **2000**. The above program may be acquired in arbitrary ways. For example, the program may be acquired from a storage medium (such as a DVD disc or a USB memory) that stores this program. The program may also be acquired by downloading, for example, the program from a server apparatus that manages a storage medium storing the program.

**[0041]** The computer **500** includes a bus **502**, a processor **504**, a memory **506**, a storage device **508**, an input/output interface **510**, and a network interface **512**. The bus **502** is a data transmission path for enabling the processor **504**, the memory **506**, the storage device **508**, the input/output interface **510**, and the network interface **512** to transmit and receive data among them. However, the method for connecting the processor **504** and the like to one another is not limited to the bus connection.

**[0042]** The processor **504** may be any type of processor such as a Central Processing Unit (CPU), a Graphics Processing Unit (GPU), or a Field-Programmable Gate Array (FPGA). The memory **506** is a main memory unit that is implemented using a Random Access Memory (RAM) or the like. The storage device **508** is an auxiliary storage device that is implemented by using a hard disk, a Solid State Drive (SSD), a memory card, or a Read Only Memory (ROM).

**[0043]** The input/output interface **510** is an interface for connecting the computer **500** with an input/output device.

An input device such as a keyboard and an output device such as a display device are connected, for example, to the input/output interface **510**.

**[0044]** The network interface **512** is an interface for connecting the computer **500** to a network **600**. The network **600** may be a Local Area Network (LAN) or a Wide Area Network (WAN). In FIG. **4**, for example, the computer **500** is connected to the camera **40** via the network **600** in such a way that the computer **500** is able to communicate with the camera **40**. However, the method for connecting the computer **500** to the camera **40** in such a way that they can communicate with each other is not limited to the connection via a network. Further, it is sufficient for the computer **500** to be capable of acquiring captured images **10** generated by the camera **40**, and the computer **500** is not required to be connected with the camera **40** in a communicable manner.

**[0045]** The storage device **508** stores a program for implementing each functional configuration unit of the key point correction apparatus **2000** (a program for implementing the above-mentioned application). The processor **504** loads this program into the memory **506** to execute the loaded program, thereby implementing each functional configuration unit of the key point correction apparatus **2000**.

**[0046]** The key point correction apparatus **2000** may be implemented with one computer **500** or may be implemented with a plurality of computers **500**. In the latter case, the configuration of the computers **500** are not required to be the same as each other, and may be different from each other.

<Flow of Process>

**[0047]** FIG. **5** is a flowchart illustrating a flow of process executed by the key point correction apparatus **2000** according to the first embodiment. The flow of process shown in FIG. **5** is a merely example and the flow of the process executed by the key point correction apparatus **2000** is not limited to the one shown in FIG. **5**.

**[0048]** Steps S**102** to S**120** form a loop process L**1**. The loop process L**1** is repeatedly executed until a predetermined termination condition is satisfied. The termination condition of the loop process L**1** may be arbitrary one. The termination condition may be, for example, a condition that "there is no new captured image **10**" or a condition that "a predetermined user operation is performed".

**[0049]** The acquisition unit **2020** acquires a captured image i (S**104**). It is noted that the acquisition unit **2020** acquires captured images **10** in an ascending order of the time at which the captured images **10** is generated. The detection unit **2040** detects key points **30** of each of one or more target objects **20** from the captured image i (S**106**).

**[0050]** Steps S**108** to S**118** form loop process L**2**. The loop process L**2** is executed for each of the target objects **20** detected from the captured image i. In S**108**, the key point correction apparatus **2000** decides whether or not there are target objects **20**, among those detected from the captured image i, that has not been handled as a target of the loop process L**2** yet. When the loop process L**2** has already been executed for all the target objects **20**, the process of FIG. **5** proceeds to S**120**. On the other hand, when there are target objects **20** that has not been handled as a target of the loop process L**2** yet, one of them is selected and the loop process L**2** is executed for the selected target object **20**. The target object **20** selected here is denoted by a target object j.

**[0051]** The decision unit **2060** decides, regarding the key points **30** of the target object j, whether or not a correction parameter has already been decided (S**110**). When the correction parameter of the target object j has not been determined yet (S**110**: NO), the decision unit **2060** decides whether or not the key points **30** of the target object j satisfy the appropriacy condition (S**112**). When the key points **30** of the target object j satisfy the appropriacy condition (S**112**: YES), the determination unit **2080** determines, based on the key points **30** of the target object j detected from the captured image i, a correction parameter of the key points **30** of the target object j (S**114**). When the key points **30** of the target object j do not satisfy the appropriacy condition (S**112**: NO), the process of FIG. **5** proceeds to S**118**.

**[0052]** When the correction parameter of the target object j has already been determined in S**110** (S**110**: YES), the correction unit **2100** corrects the key points **30** of the target object j detected from the captured image i based on the correction parameter (S**116**).

**[0053]** Step S**118** is the end of the loop process L**2**. Therefore, the process of FIG. **5** proceeds to the top of the loop process L**2** (S**108**).

**[0054]** After the loop process L**2** is executed for all the target objects **20** detected from the captured image i, the process of FIG. **5** proceeds to S**120**. Since S**120** is the end of the loop process L**1**, the process of FIG. **5** proceeds to the top of the loop process L**1** (S**102**).

**[0055]** The number of cameras **40** handled by the key point correction apparatus **2000** may be one or more. In the latter case, the key point correction apparatus **2000** performs, for each of the plurality of cameras **40**, the process shown in FIG. **5** on a time series of a plurality of the captured images **10** generated by the camera **40**.

<Acquisition of Captured Images **10**: S**104**>

**[0056]** The acquisition unit **2020** acquires captured images **10** (S**104**). The captured images **10** may be acquired in arbitrary manner. For example, the captured images **10** are stored in the storage unit in advance in a manner where they are accessible from the key point correction apparatus **2000**. In this case, the acquisition unit **2020** acquires the captured images **10** by accessing the storage unit. In another example, the acquisition unit **2020** may acquire the captured images **10** by receiving the captured images **10** transmitted from another apparatus (e.g., the camera **40**).

**[0057]** The acquisition unit **2020** may acquire the captured images **10** one by one or may collectively acquire the plurality of captured images **10**. In the latter case, for example, the acquisition unit **2020** periodically accesses a storage unit that stores the captured images **10** and then collectively acquires the captured images **10** that the acquisition unit **2020** has not acquired yet.

<Detection of Key Points **30**: S**106**>

**[0058]** The detection unit **2040** detects key points **30** of the target object **20** from the captured images **10** (S**106**). In order to detect the key points **30**, first, the detection unit **2040** detects the target object **20** from the captured images **10**. Then, the detection unit **2040** detects key points **30** for each of the target objects **20** detected from the captured images **10**. It is noted that various existing techniques may be used as a technique for detecting an object of a predetermined type from an image and a technique for detecting key points of the object detected from the image. For example, a machine learning-based model (hereinafter,

called object detection model), which is trained to output key points of each of the target objects **20** included in an image in response to this image being input thereinto, is prepared in advance. The detection unit **2040** can obtain the key points **30** of each of the target objects **20** included in the captured images **10** by inputting the captured images **10** into the object detection model.

**[0059]** In order to correct, using a correction parameter of a target object **20** determined based on the appropriate image, key points **30** of the same target object **20** detected from another captured image **10**, the target object **20** needs to be tracked for a plurality of captured images **10**. In order to achieve this, the detection unit **2040** determines, for example, for each of the target objects **20** detected from the captured image **10**, whether or not the target object **20** same as that has already been detected from another captured image **10**, and allocates an identifier to the target object **20** based on the result of the determination. To the target object **20** that is determined to have been already detected from another captured image **10**, the identifier that has already been allocated is used. On the other hand, to a target object **20** that is not detected from another capture image **10**, a new identifier is allocated. Accordingly, one identifier is allocated to the same target objects **20** as each other that are detected from each of a plurality of captured images **10**. It is therefore possible to track one target object **20** for a plurality of captured images **10**.

**[0060]** It is noted that various existing techniques may be used as a technique for determining whether or not the target objects **20** detected from captured images **10** that are different from each other are the same as each other. For example, by comparing features of the target objects **20** obtained from the captured images **10** that are different from each other, it can be determined whether or not they are the same as each other. When this method is used, for example, the above-mentioned object detection model that is used for detecting the key points **30** is configured to have a function of outputting features of the detected target objects **20**. Accordingly, the detection unit **2040** can obtain the features and the key points **30** of each target object **20** detected from the captured images **10**.

<Determination of Whether Appropriacy Condition is Satisfied: S**112**>

**[0061]** The decision unit **2060** decides whether or not the key points **30** detected for the target object j satisfy the appropriacy condition (S**112**). The appropriacy condition is a condition that is satisfied when the key points **30** detected for the target object j are suitable for determining a correction parameter. In the following, some specific examples of conditions that may be employed as the appropriacy condition will be described.

Example 1: Condition Regarding Position or Posture of Target Object **20**

**[0062]** The appropriacy condition may be, for example, a condition that "the position, the size, or the posture of the target object j, or a combination of two or more of them are included in a predetermined range". Hereinafter, this predetermined range will be referred to as a decision range. When the above appropriacy condition is used, regarding the position, the size, or the posture of the target object j, or a combination of two or more of them, a range suitable for determining the correction parameter is defined in advance as the decision range. Then, it is determined that the appropriacy condition is satisfied when the position, the size, or the posture of the target object j that is determined based on the key points **30** detected from the captured image i, or a combination of two or more of them is included in a range suitable for determining the correction parameter (i.e., decision range). On the other hand, it is determined that the appropriacy condition is not satisfied when the position, the size, or the posture of the target object j determined based on the key points **30** detected from the captured image i, or a combination of two or more of them is not included in the decision range.

**[0063]** If the range of the position of the target object j is included in the decision range, the decision unit **2060** determines the position of the target object j using the key points **30** of the target object j. The position of the target object j may be represented, for example, by the position of a specific point of the target object j (the centroid or the like). Suppose that the position of the target object j is represented by the position of the centroid of the target object j. In this case, the decision unit **2060** computes the position of the centroid of the key points **30** of the target object j detected from the captured image i, and uses the position of the centroid as a parameter that represents the position of the target object j.

**[0064]** Here, suppose that the position of the target object j is represented by coordinates on a k-dimensional space (k is 2 or 3). In this case, the decision range of the position of the target object j can be represented by a partial space in the k-dimensional space. That is, the appropriacy condition that "the position of the target object j is included in the decision range" is satisfied when the coordinates on the k-dimensional space representing the position of the target object j detected from the captured image i are included in the decision range that is a partial space on the k-dimensional space.

**[0065]** When the range of the size of the target object j is included in the decision range, the decision unit **2060** determines the size of the target object j using the key points **30** of the target object j detected from the captured image i. There are various methods for representing the size of the target object j. Suppose that the key points **30** represent vertices of the bottom surface of a three-dimensional bounding box of the target object j projected onto the road. In this case, the decision unit **2060** uses the key point correspondence points **80** on the orthoimage **50** to determines a rectangular area that represents the target object j on the orthoimage **50**, and uses (w, h), which is a combination of the width w and the height h of this rectangular area, as a parameter that represents the size of the target object j.

**[0066]** There are various methods for determining a rectangular area that represents the target object j on the orthoimage **50**. Here, with reference to FIG. **6**, a specific example thereof will be described. FIG. **6** is a diagram illustrating a method for determining the rectangular area that represents the target object j. In FIG. **6**, the key point correspondence points **80** of the target object j are key point correspondence points **80-1** to **80-4**.

**[0067]** First, the decision unit **2060** determines one of the key point correspondence points **80** of the target object j that is the closest to the camera **40**. Suppose that the key point correspondence point **80** that is the closest to the camera **40** is the key point correspondence point **80-2** in FIG. **6**. Next,

from two key point correspondence points **80** that are adjacent to the key point correspondence point **80-2** in a rectangle that is formed by the key point correspondence points **80-1** to **80-4**, the decision unit **2060** determines the key point correspondence point **80** with which the longer line segment is obtained by connecting it to the key point correspondence point **80-2** (which is farther from the key point correspondence point **80-2**). In FIG. **6**, the key point correspondence points **80** that are adjacent to the key point correspondence point **80-2** are the key point correspondence points **80-1** and **80-3**. The line segment that connects the key point correspondence point **80-1** to the key point correspondence point **80-2** is longer than the line segment that connects the key point correspondence point **80-3** to the key point correspondence point **80-2**. Therefore, the key point correspondence point **80** to be determined is the key point correspondence point **80-1**.

**[0068]** The decision unit **2060** determines, as a rectangular area **100** that represents the target object j, a rectangular area that has a line segment connecting the key point correspondence point **80-1** determined above and the key point correspondence point **80-2** as a long side **90-1** and whose another long side **90-2** passes near the key point correspondence points **80-3** and **80-4**. There are various methods for determining the long side **90-2**. For example, the long side **90-2** is determined in such a way that the distance between the long side **90-1** and the long side **90-2** (i.e., the length of the short side of the rectangular area **100**) becomes equal to the distance between the long side **90-1** and the key point correspondence point **80-3**, the distance between the long side **90-1** and the key point correspondence point **80-4**, or the average of these two distances. In the example shown in FIG. **6**, the distance between the long side **90-1** and the long side **90-2** is the average of the distance between the long side **90-1** and the key point correspondence point **80-3** and the distance between the long side **90-1** and the key point correspondence point **80-4**.

**[0069]** When the size of the target object j is represented by the width and the height as described above, the decision range regarding the size of the target object j is represented by a partial space in a two-dimensional space. That is, when the size of the target object j is represented by (w, h), which is a combination of the width with the height, the decision range regarding the size of the target object j can be represented by a partial space in a wh space. Therefore, the appropriacy condition that "the size of the target object j is included in the decision range" is satisfied when the size (w[i,j]), h[i,j]) of the target object j detected from the captured image i is included in the decision range, which is the partial space in the wh space.

**[0070]** The size of the target object j may be represented in three dimensions. Suppose that eight respective vertices of a three-dimensional bounding box of the target object j is detected as the key points **30**. In this case, the size of the target object j can be represented by (w, d, h), which is a combination of the width w, the depth d, and the height h of the three-dimensional bounding box. In this case, the decision range regarding the size of the target object j is represented by a partial space in a three-dimensional space. Therefore, the appropriacy condition that "the size of the target object j is included in the decision range" is satisfied when the size (w[i,j], d[i,j], h[i,j]) of the target object j detected from the captured image i is included in the decision range, which is a partial space in the hdw space.

**[0071]** When the range of the posture of the target object j is included in the appropriacy condition, the decision unit **2060** determines the posture of the target object j using the key points **30** of the target object j detected from the captured image i. There are various methods for representing the posture of the target object j. For example, the posture of the target object j is represented by a posture angle θ of the target object j on the orthoimage **50**. The posture angle of the target object j on the orthoimage **50** may be represented, for example, by the angle of a reference axis of the target object j with respect to a reference axis (e.g., horizontal axis) of the orthoimage **50**. The reference axis of the target object j may be, for example, the long side or the short side of the rectangular area **100** that represents the target object j described in FIG. **6**.

**[0072]** When the posture of the target object j is represented by the posture angle of the target object j as described above, the decision range regarding the posture of the target object j is represented by a partial space in one dimension (i.e., numerical range of the posture angle θ). Therefore, the appropriacy condition that "the posture of the target object j is included in the decision range" is satisfied when the posture angle θ[i,j] of the target object j detected from the captured image i is included in the decision range, which is a predetermined numerical range.

**[0073]** The posture of the target object j may be represented by the posture thereof on a three-dimensional space. In this case, for example, the posture of the target object j may be represented by (pitch θ, roll φ, yaw ψ), which is a combination of angles that the three-dimensional bounding box of the target object j forms with respect to the reference axes of the three respective directions. In this case, the decision range regarding the posture of the target object j is represented by a partial space in the three-dimensional space. Therefore, the appropriacy condition that "the posture of the target object j is included in the decision range" is satisfied when the posture (θ[i,j], φ[i,j], ψ[i,j]) of the target object j detected from the captured image i is included in a decision range, which is a partial space in the θφψ space.

**[0074]** As described above, the decision range may be defined for a combination of two or more of the position, the size, and the posture of the target object j. Suppose that the decision range is defined as a range of (x, y, θ), which is a combination of the position (x, y) and the posture θ of the target object j. In this case, the decision unit **2060** determines whether or not a combination (x[i,j], y[i,j], θ[i,j]) of the position and the posture of the target object j detected from the captured image i is included in the decision range.

**[0075]** In another example, suppose that the decision range is defined as a range of (x, y, w, h, θ), which is a combination of the position (x, y), the size (w, h), and the posture θ of the target object j. In this case, the decision unit **2060** determines whether or not a combination (x[i,j], y[i,j], w[i,j], h[i,j], θ[i,j]) of the position, the size, and the posture of the target object j detected from the captured image i is included in the decision range.

**[0076]** It is noted that when the decision range includes the range regarding the size of the target object j, the decision rage can be determined for each type of the target object j if the position or the posture of the target object j suitable for determining the correction parameter varies for each of the target objects of different sizes, such as a bus, a truck, a passenger car, or a person. On the other hand, if the range of the position or the posture that is suitable for determining the

correction parameter does not vary greatly even when the sizes of the target objects j are different from one another, it is possible to reduce the amount of the computation required to decide whether or not the appropriacy condition is satisfied or to reduce the time required to perform this computation, by excluding the size of the target object j from the decision range.

**[0077]** A method for defining the decision range will be described later.

Example 2: Condition Regarding Time Stability of Key Points **30**

**[0078]** In another example, the appropriacy condition may be a condition that "time stability of the key points **30** of the target object j is high". The time stability of the key points **30** being high means that a change over time of the key points **30** is small. If this appropriacy condition is used, the decision unit **2060** computes an index value representing time stability (hereinafter, called a time stability index value) for the key points **30** of the target object j detected from the captured image i. In this case, as a more specific appropriacy condition, a condition that "the time stability index value computed for the key points **30** of the target object j is equal to or smaller than a threshold" may be used. Therefore, when the time stability index value is equal to or smaller than the threshold, it is determined that the detection condition is satisfied. On the other hand, when the time stability index value is larger than the threshold, it is determined that the detection condition is not satisfied.

**[0079]** The time stability index value is computed based on, for example, a change over time of the size of the target object j in the captured image i. The time stability index value is computed using, for example, the following Expression (1).

[Expression 1]

$$E_{i,j} = \sum_{T_i - P \le t \le T_i} \left\| \frac{\partial (w_j(t),\, h_j(t))}{\partial t} \right\| \tag{1}$$

**[0080]** E_(i,j) denotes the time stability index value regarding the target object j detected from the captured image i. This time stability index value represents the time stability of the size of the target object j. For notational convenience, subscripts are shown by underscores in parts other than expressions. (w(t)_j, h(t)_j) represents the size of the target object j detected from the captured image **10** at time t. The method for computing the size of the target object **20** has already been described above. The symbol ||a|| denotes a norm of a vector a. In Expression (1), the time stability index value can be represented by the total amount of the change over time of the size of the target object j in a period having a length P ended at a time T_i at which the captured image i has been generated.

**[0081]** Further, if the captured images **10** are generated at regular time intervals (if the camera **40** captures images at constant intervals), the time stability index value may be computed by the following Expression (2).

[Expression 2]

$$E_{i,j} = \sum_{N_i - Np \le t \le N_i} \| (w[t,\, j],\, h[t,\, j]) - (w[t-1,\, j],\, h[t-1,\, j]) \| \tag{2}$$

**[0082]** N_i denotes a frame number of the captured image i and corresponds to the time T_i of Expression (1). N_p represents the length P of the period used to compute the time stability index value in terms of the number of captured images **10**. (w[t,j], h[t,j]) denotes the size of the target object j detected from a captured image **10** whose frame number is t.

**[0083]** Here, the magnitude of the reliability of the key points **30** may be taken into account to compute the time stability index value. In this case, the time stability index value can be represented, for example, by the following Expression (3).

[Expression 3]

$$F_{i,j} = \alpha * \sum_{T_i - P \le t \le T_i} \frac{1}{r(t)_j} + \beta * E_{i,j} \tag{3}$$

$$\text{s.t. } \alpha + \beta = 1$$

**[0084]** F_(i,j) represents the time stability of the key points **30** of the target object j detected from the captured image i in which the reliability of the key points **30** is taken into account. r(t)_j denotes the magnitude of the reliability of the key points **30** of the target object j detected from the captured image **10** at a time t. An inverse number of r(t)_j is used so that the time stability index value decreases as the reliability becomes higher. E_(i,j) is time stability of the key points **30** of the target object j detected from the captured image i that is computed not taking the reliability of the key points **30** into account. E_(i,j) is computed using, for example, Expressions (1) or (2). The symbols α and β are weight coefficients assigned to the first term and the second term, respectively.

**[0085]** Various existing methods may be used as the method for computing the reliability of the key points **30**. For example, by tracking key points using filtering such as a Kalman filter, it is possible to compute the reliability of the key points from a covariance matrix of state variables.

Example 3: Combination of Example 1 with Example 2

**[0086]** The decision unit **2060** may use the aforementioned Example 1 and Example 2 in combination with each other. In the following, the appropriacy condition described in Example 1 is referred to as an appropriacy condition 1 and the appropriacy condition described in Example 2 is referred to as an appropriacy condition 2. If both the appropriacy condition 1 and the appropriacy condition 2 are satisfied, the decision unit **2060** decides that the appropriacy condition is satisfied. On the other hand, if at least one of the appropriacy condition 1 and the appropriacy condition 2 is not satisfied, the decision unit **2060** decides that the appropriacy condition is not satisfied.

**[0087]** For example, first, the decision unit **2060** computes the position or the like of the target object j detected from the

captured image i and determines whether or not the computed position or the like is included in the decision range (i.e., whether or not the appropriacy condition 1 is satisfied). If the appropriacy condition 1 is not satisfied, the decision unit **2060** decides, regarding the target object j detected from the captured image i, the appropriacy condition is not satisfied (S**112**: NO). On the other hand, if the appropriacy condition 1 is satisfied, the decision unit **2060** decides whether or not the time stability of the target object j detected from the captured image i is high (i.e., whether or not the appropriacy condition 2 is satisfied). If the appropriacy condition 2 is not satisfied, the decision unit **2060** decides, regarding the target object j detected from the captured image i, that the appropriacy condition is not satisfied (S**112**: NO). On the other hand, if the appropriacy condition 2 is satisfied, the decision unit **2060** decides, regarding the target object j detected from the captured image i, that the appropriacy condition is satisfied (S**112**: YES).

**[0088]** In another example, if at least one of the appropriacy condition 1 and the appropriacy condition 2 is satisfied, the decision unit **2060** may decides that the appropriacy condition is satisfied. In this case, it is decided that the appropriacy condition is not satisfied only when neither the appropriacy condition 1 nor the appropriacy condition 2 is satisfied.

<Determination of Correction Parameter: S**114**>

**[0089]** The determination unit **2080** determines the correction parameter regarding the target object j using the key points **30** of the target object j detected from the captured image i that corresponds to the target object j (S**114**). The correction parameter is a parameter representing, for example, the size of the target object j. For example, when the size of the target object j is represented by the width w and the height h, the determination unit **2080** determines the size (w[i,j], h[i,j]) of the target object j detected from the captured image i as the correction parameter.

**[0090]** Suppose that the size of the target object j is represented by the width w, the depth d, and the height h. In this case, the determination unit **2080** determines the size (w[i,j], d[i,j], h[i,j]) of the target object j detected from the captured image i as the correction parameter.

**[0091]** The determination unit **2080** put the correction parameter that has been decided into a storage unit, which is accessible from the key point correction apparatus **2000**, in association with identification information of the corresponding target object j. The determination regarding whether the correction parameter of the target object j has already been decided (S**110**) can be made by determining, for example, whether or not the correction parameter that corresponds to the target object j is stored in this storage unit.

<<Update of Correction Parameter>>

**[0092]** In the flowchart shown in FIG. **5**, whether or not the appropriacy condition is satisfied is not decided for the target object j for which a correction parameter has already been determined. However, even when a correction parameter has already been decided for the target object j detected from the captured image i, it is possible that the key points **30** of the target object j detected from the captured image i satisfy the appropriacy condition and that a correction parameter that is more suitable than the current correction parameter may be obtained from the key points **30**. In this case, for example, the key point correction apparatus **2000** may update the correction parameter in a case in which a correction parameter has already been determined.

**[0093]** FIG. **7** is a flowchart illustrating a flow of process of the key point correction apparatus **2000** having a function of updating the correction parameter. In FIG. **7**, when the correction parameter of the target object j has already been determined (S**110**), it is decided whether or not to update the correction parameter (S**202**). If it is decided that the correction parameter will be updated (S**202**: YES), a correction parameter is newly determined (S**114**).

**[0094]** There are various methods for determining whether or not to update the correction parameter in S**202**. Suppose that a plurality of decision ranges whose priorities are different from one another are defined in a case in which the aforementioned appropriacy condition 1 is used. In this case, if a correction parameter has been determined using the key points **30** of the target object j detected from the captured image i as a result of these key points **30** satisfying the appropriacy condition, the determination unit **2080** sets the priority of the decision range that corresponds to this appropriacy condition as the priority of the correction parameter. The information representing the priority of the correction parameter is stored in the storage unit along with the correction parameter.

**[0095]** In S**202**, the determination unit **2080** decides, for another captured image i obtained afterwards, whether or not the key points **30** of the target object j detected from the captured image i satisfy the appropriacy condition. If the appropriacy condition is not satisfied, the determination unit **2080** decides that the correction parameter will not be updated. On the other hand, if the appropriacy condition is satisfied, the determination unit **2080** further decides whether or not the priority of the decision range that corresponds to the satisfied appropriacy condition is higher than the priority of the current correction parameter that corresponds to the target object j. When the priority of the decision range that corresponds to the satisfied appropriacy condition is higher than the priority of the current correction parameter that corresponds to the target object j, the correction parameter is updated. On the other hand, when the priority of the decision range that corresponds to the satisfied appropriacy condition is not higher than the priority of the current correction parameter that corresponds to the target object j, the correction parameter is not updated.

**[0096]** Suppose that a decision range R**1** of a priority 1, a decision range R**2** of a priority 2, and a decision range R**3** of a priority 3 are defined. It is assumed here that the priority becomes higher as the numerical value thereof becomes larger. In this case, it is assumed that the appropriacy condition has been satisfied since the position or the like of the target object j detected from the captured image i is included in the decision range R**2**. It is further assumed that the correction parameter has not yet been determined for the target object j. In this case, the determination unit **2080** determines the correction parameter using the key points **30** of the target object j detected from the captured image. In this case, the priority of the correction parameter is set as 2.

**[0097]** Suppose that the appropriacy condition has been satisfied afterwards since the position or the like of the target object j detected from another captured image i is included in the decision range R**1**. In this case, the priority of the

appropriacy condition satisfied here is 1, which is lower than the priority 2 of the current correction parameter that corresponds to the target object j. Therefore, the correction parameter is not updated.

**[0098]** Suppose that the appropriacy condition has been satisfied afterwards since the position or the like of the target object j detected from another captured image i is included in the decision range R**3**. In this case, the priority of the appropriacy condition satisfied here is 3, which is higher than the priority 2 of the current correction parameter that corresponds to the target object j. Therefore, the determination unit **2080** determines the correction parameter using the key points **30** of the target object j detected from the captured image i and updates the correction parameter. The priority 3 is associated with the correction parameter.

**[0099]** In a case in which the aforementioned appropriacy condition 2 is used, it is possible to decide whether or not to update the correction parameter based on the size of the time stability index value. Specifically, if a correction parameter has been determined using key points **30** of the target object j detected from the captured image i as a result of the key points **30** satisfying the appropriacy condition 2, the determination unit **2080** sets the computed time stability index value as a value representing the priority of this correction parameter. The smaller the time stability index value is, the more useful. Therefore, the smaller the time stability index value is, the higher the priority is.

**[0100]** After that, when the key points **30** of the target object j detected from another captured image i have satisfied the appropriacy condition 2, the determination unit **2080** decides whether or not the computed time stability index value is smaller than the value set as the priority of the current correction parameter that corresponds to the target object j. When the computed time stability index value is smaller than the value of the priority, the correction parameter is updated. On the other hand, when the computed time stability index value is not smaller than the value of the priority, the correction parameter is not updated.

**[0101]** In a case in which the time stability index value is slightly smaller than the value of the priority, a more appropriate correction parameter should be obtained. However, it is possible that the effects obtained by the update of the correction parameter may not be large. In this case, for example, the correction parameter may be updated only in a case in which the computed time stability index value is smaller than the value of the priority and the difference between them is sufficiently large (equal to or larger than a threshold).

<Correction of Key Points **30**: S**116**>

**[0102]** When the target object j has been detected from the captured image i generated after the captured image **10** that corresponds to the target object j (S**110**: YES), the correction unit **2100** corrects the key points **30** of the target object j detected from the captured image i using the correction parameter that corresponds to the target object j (S**116**). The captured image **10** regarding which key points **30** are to be corrected is referred to as an image to be corrected.

**[0103]** Suppose that the size (w, h) of the target object j is determined as the correction parameter that corresponds to the target object j. In this case, the correction unit **2100** computes, for each of the key points **30** of the target object j on the captured image i, the key point correspondence points **80** on the orthoimage **50** by perform orthorectification on the image to be corrected. The correction unit **2100** further generates a correction rectangle, which is a rectangular area of the size (w, h), based on the arrangement of the key point correspondence points **80** on the orthoimage **50** and corrects the key point correspondence points **80** in such a way that the key point correspondence points **80** becomes respective vertices of the correction rectangle. After that, the correction unit **2100** converts the respective key point correspondence points **80** after the correction into points on the image to be corrected by performing inverse conversion for making the orthoimage **50** back to the image to be corrected. The points on the image to be corrected that are obtained as described above are used as the key points **30** after the correction.

**[0104]** Now, a method for correcting the key point correspondence points **80** will be explained. The correction unit **2100** associates, for example, the respective key point correspondence points **80** of the target object **20** with respective vertices of a correction rectangle having the size (w, h). The correction unit **2100** further determines the arrangement of the correction rectangle in such a way that the sum of the distances between corresponding points is minimized. The correction unit **2100** then changes the positions of the respective key point correspondence points **80** to the positions of the vertices of the corresponding correction rectangle. Further, when there is no key point correspondence point **80** that corresponds to the vertex of the correction rectangle, the correction unit **2100** generates new key point correspondence points **80** that correspond to the vertex. In this way, by correcting the position of the key point correspondence points **80** and generating the key point correspondence points **80** using the correction rectangle, the key point correspondence points **80** are corrected.

**[0105]** FIG. **8** is a diagram illustrating a method for correcting the key point correspondence points **80** using a correction rectangle. The case shown in the upper part of FIG. **8** is a case in which there are four key point correspondence points **80**. In this case, the arrangement of a correction rectangle **110** is determined based on the positions of the key point correspondence points **80-1**, **80-2**, **80-3**, and **80-4**. Then, the positions of the key point correspondence points **80-1**, **80-2**, **80-3**, and **80-4** are corrected to the positions of vertices **120-1**, **120-2**, **120-3**, and **120-4**, respectively.

**[0106]** The case shown in the middle part of FIG. **8** is a case in which there are three key point correspondence points **80**. In this case, the arrangement of the correction rectangle **110** is determined based on the positions of the key point correspondence points **80-1**, **80-2**, and **80-3**. Then, the positions of the key point correspondence points **80-1**, **80-2**, and **80-3** are respectively corrected to the positions of vertices **120-1**, **120-2**, and **120-3**. Further, a new key point correspondence point **80** is generated in the position of the vertex **120-4**.

**[0107]** The case shown in the lower part of FIG. **8** is a case in which there are two key point correspondence points **80**. In this case, the arrangement of the correction rectangle **110** is determined based on the positions of the key point correspondence points **80-1** and **80-2**. Then, the positions of the key point correspondence points **80-1** and **80-2** are respectively corrected to the positions of vertices **120-2** and **120-3**. Further, new key point correspondence points **80** are generated in the position of the vertex **120-1** and the position of the vertex **120-4**.

**[0108]** When there are two key point correspondence points **80** of the target object **20**, the arrangement of the correction rectangle **110** varies depending on which part of the target object **20** (right front, left front, right back, or left back) each of the key point correspondence points **80** represents. In the case in the lower part of FIG. **8**, for example, an arrangement in which the key point correspondence point **80-1** and the key point correspondence point **80-2** are associated with the vertex **120-1** and the vertex **120-4**, respectively, may be employed.

**[0109]** In view of the above, for example, the detection unit **2040** is configured to determine which part of the target object **20** is represented by the key point **30** when detecting the key points **30**. The correction unit **2100** then acquires information indicating which part of the target object **20** is represented by the key point **30**, and associates the vertices **120** of the correction rectangle **110** with the key point correspondence points **80** using the acquired information.

**[0110]** Arbitrary method may be employed as a method for configuring the detection unit **2040** so as to be able to determine which part of the target object **20** is represented by the key point **30**. Suppose that key points **30** are detected using the object detection model, as described above. In this case, the object detection model is configured so as to output the key points **30** in a manner where it is possible to know which part of the target object **20** is represented by the key point **30**. Suppose, as a more specific example, that the object detection model is implemented by with a neural network. In this case, what each output node of the object detection model means is defined at the time of training of the object detection model. Therefore, the correction unit **2100** is able to determine which part of the target object **20** is represented by a key point correspondence point **80** based on from which output node of the object detection model the key point **30** corresponding to the key point correspondence point **80** of the target object **20** is output.

<Output of Results>

**[0111]** The key point correction apparatus **2000** outputs information indicating the results of the process. Hereinafter, information output by the key point correction apparatus **2000** will be referred to as output information. The output information includes at least information indicating key points **30** regarding each of the target objects **20** detected from each of the captured images **10**. The information indicating the key points **30** is, for example, coordinates of the key points **30** in the target object **20**.

**[0112]** In a case in which key points **30** are corrected by the correction unit **2100**, the output information includes, at least, information indicating the key points **30** after the correction. In this case, information indicating the key points **30** before the correction may or may not be included in the output information.

**[0113]** The output information may include an image generated by superimposing key points **30** of the target object **20** or an image representing a three-dimensional bounding box on the captured image **10**. In this image, key points **30** that are not corrected and key points **30** that are corrected may be distinguished from each other. For example, a mark that shows the key points **30** that are corrected and a mark that shows the key points **30** that are not corrected may be of colors different from each other so that they can be distinguished from each other.

<Method for Generating Decision Range>

**[0114]** If the aforementioned appropriacy condition 1 is used, the decision range needs to be generated in advance. In the following, a method for generating the decision range will be explained. An apparatus having a function of generating the decision range is referred to as a decision range generation apparatus. The decision range generation apparatus may either be integrated with the key point correction apparatus **2000** (implemented with one computer) or may be separated from the key point correction apparatus **2000** (implemented with computers different from each other).

**[0115]** When the decision range generation apparatus is integrated with the key point correction apparatus **2000**, the key point correction apparatus **2000** includes a decision range generation unit that implements the function of the decision range generation apparatus. FIG. **9** is a block diagram illustrating a functional configuration of the key point correction apparatus **2000** including the decision range generation unit. It is assumed, in the following description, that it is the decision range generation unit **2120** that generates the decision range in order to simplify the explanation. When the decision range generation apparatus is separated from the key point correction apparatus **2000**, it is the decision range generation apparatus that performs the process described below.

**[0116]** The decision range may be generated, for example, by clustering with training images. Captured images obtained from the camera **40** may be used as the training images. A ground-truth key point is added to a training image. A ground-truth key point in a training image represents the key point that should be detected from this training image. For example, the ground-truth key point is manually determined by a user or the like of the decision range generation apparatus.

**[0117]** FIG. **10** is a flowchart illustrating a flow of process of generating a decision range using training images. S**302** to S**316** form loop process L**3**. The loop process L**3** is executed for each of the training images. In S**302**, the decision range generation unit **2120** determines whether or not there are training image that have not yet been subjected to the loop process L**3**. If the loop process L**3** has already been executed for all the training images, the process of FIG. **10** proceeds to S**318**. On the other hand, if there are training images that have not yet been subjected to the loop process L**3**, one of them is selected and the loop process L**3** is executed for the selected training image. The training image selected here is referred to as a training image k.

**[0118]** The decision range generation unit **2120** detects key points **30** of each of one or more target objects **20** from the training image k (S**304**). The process of detecting the key points **30** of each of the target objects **20** from the training image k is realized by process similar to the process in which the detection unit **2040** detects the key points **30** of each of the target objects **20** from the captured images **10**. Therefore, for example, the detection unit **2040** is used for the process of detecting the key points from the training image k.

**[0119]** The process from S**306** to S**314** form loop process L**4**. The loop process L**4** is executed for each target object **20** that has been detected from the training image k. In S**306**, the decision range generation unit **2120** determines whether or not there are target objects **20** detected from the training image k that have not yet been subjected to the loop process L**4**. When the loop process L**4** has already been executed for all the target objects **20**, the process of FIG. **10** proceeds to

S316. On the other hand, if there are target objects **20** that have not yet been subjected to the loop process L**4**, one of them is selected and the loop process L**4** is executed for the selected target object **20**. The target object **20** selected here is denoted by a target object m.

**[0120]** The decision range generation unit **2120** computes an error index value representing an error between the key points **30** detected for the target object m and the ground-truth key point for the target object m (S**308**). The error index value is, for example, a statistical value (e.g., an average value) of the distance between the key points **30** and the ground-truth key point corresponding to each other. Suppose that the ground-truth key points A**1**, A**2**, A**3**, and A**4** are set for the target object m of the training image k. Further suppose that B**1**, B**2**, B**3**, and B**4** have been detected from the training image k as the key points **30** of the target object m. The decision range generation unit **2120** first associates the ground-truth key points with the key points **30**. For example, the decision range generation unit **2120** associates each ground-truth key point of the target object m with the key point **30** of the target object m that is the closest to that ground-truth key point. Suppose that key points B**1**, B**2**, B**3**, and B**4** have been associated with the ground-truth key points A**1**, A**2**, A**3**, and A**4**, respectively. In this case, the decision range generation unit **2120** computes a statistical value of the distance between A**1** and B**1**, the distance between A**2** and B**2**, the distance between A**3** and B**3**, and the distance between A**4** and B**4** as an error index value.

**[0121]** The decision range generation unit **2120** determines whether or not the error index value computed for the target object m is equal to or smaller than a threshold (S**310**). If the error index value is equal to or smaller than the threshold (S**310**: YES), the decision range generation unit **2120** computes a feature vector using the key points **30** of the target object m detected from the training image k.

**[0122]** The feature vector represents features such as the position or the posture of the target object m. Suppose that the position (x, y), the size (w, h), and the posture θ are used as the features of the target object m. In this case, the feature vector is represented by a five-dimensional vector (x, y, w, h, θ).

**[0123]** After the feature vector is computed or after it is determined that the error index value is larger than the threshold (S**310**: NO), the process of FIG. **10** proceeds to S**314**. Since S**314** is the end of the loop process L**4**, the process of FIG. **10** proceeds to the top of the loop process L**4** (S**306**).

**[0124]** After the loop process L**4** has ended for the training image k, the process of FIG. **10** proceeds to S**316**. Since S**316** is the end of the loop process L**3**, the process of FIG. **10** proceeds to the top of the loop process L**3** (S**302**).

**[0125]** After the loop process L**3** is performed for each of the training images, the decision range generation unit **2120** clusters the plurality of feature vectors that are computed so far (S**318**). The error index value being equal to or smaller than the threshold means that the key points **30** of the target object m detected from the training image k is close to the ground-truth key points (in other words, that the key points **30** are detected with high accuracy). Therefore, when the error index value is equal to or smaller than the threshold, the feature vector of the target object m detected from the training image k represents the position, the posture or the like of the target object m for which key-points can be detected accurately. Therefore, the decision range generation unit **2120** uses the feature vector that can be obtained when the error index value becomes equal to or smaller than the threshold, thereby determining a range of the position or the posture of the target object for which key points can be detected accurately, and handles this range as a decision range.

**[0126]** Various existing techniques may be used as a specific method for classifying a plurality of vectors by clustering. The decision range generation unit **2120** classifies the feature vectors into a plurality of clusters by, for example, approximating the distribution of the feature vectors using a mixed Gaussian distribution represented by the following Expression (4).

[Expression 4]

$$\min E = \sum_{u=1}^{U} \sum_{v=1}^{V_u} \|p_v - c_u\|^2 \tag{4}$$

**[0127]** The symbol u denotes an identifier of the cluster and U denotes the total number of clusters. The symbol v denotes an identifier of a feature vector in the cluster and V_u denotes the total number of feature vectors included in the clusters u. The symbol p_v denotes a feature vector. The symbol c_u denotes the centroid of the cluster u.

**[0128]** Each centroid c_u that minimizes E may be determined using, for example, the Expectation-Maximization (EM) method such as the k-means method. Further, various existing techniques may be used as a method for determining an appropriate total number of clusters in the clustering.

**[0129]** The decision range generation unit **2120** generates a decision range based on the results of the clustering (S**320**). Specifically, first, the decision range generation unit **2120** computes, for each of the plurality of clusters generated by clustering, the stability index value representing the stability of the cluster. The stability index value can be computed as a value that becomes larger as the degree of scattering of the feature vectors included in the cluster decreases. The stability index value is computed using, for example, the following Expression (5).

[Expression 5]

$$S = \left\| \begin{pmatrix} \sigma_{hh} & \sigma_{hw} \\ \sigma_{hw} & \sigma_{ww} \end{pmatrix} \right\|^{-1} \tag{5}$$

**[0130]** The symbol S denotes a stability index value. The symbol ||A|| denotes a norm of a matrix A. Further, the matrix whose norm is computed in Expression (5) is a covariance matrix of feature vectors in a cluster projected onto the wh space.

**[0131]** The decision range generation unit **2120** generates a decision range from a cluster whose stability index value is equal to or larger than a threshold. If there are a plurality of clusters whose stability index values are equal to or larger than the threshold, a decision range is generated for each of the clusters. In a case in which a plurality of decision ranges are thus generated, the aforementioned priority may be allocated to each of the decision ranges. For example, higher priorities are allocated to clusters with larger stability index values.

**[0132]** Now, a method for generating a decision range from clusters will be explained. For example, the decision range generation unit **2120** computes the centroid of the clusters and sets a region near the centroid as the decision range. The region near the centroid may be, for example, a region obtained by adding a predetermined range to the value of the centroid for each of the elements of the feature vectors. Suppose that a feature vector is represented by a five-dimensional vector (x, y, w, h, θ) that represents the position (x, y), the size (w, h), and the posture θ of the target object **20**. Further suppose that the centroid of the clusters is (xc, yc, wc, hc, θc). In this case, for example, the decision range may be "$xc-\alpha<x<xc+\alpha$, $yc-\alpha<y<yc+\alpha$, $wc-\alpha<w<wc+\alpha$, $hc-\alpha<h<hc+\alpha$, and $\theta c-\alpha<\theta<\theta c+\alpha$" in which a predetermined width is added to each element from the centroid. It is noted that although the size of the range around the centroid is a fixed value a for all the elements in this example, the size of the range may vary for each element. For example, the ranges of the respective elements may be determined using the degree of scattering of each element in a cluster (dispersion or standard deviation).

**[0133]** Further, the decision range generation unit **2120** may generate the decision range using only some of the elements that are used to generate the clusters. For example, when a feature vector is represented by a five-dimensional vector that represents the position, the size, and the posture of the target object **20**, as described above, the decision range generation unit **2120** may generate a decision range as a range of a three-dimensional space that represents the position and the posture of the target object **20**. This corresponds to generating a decision range from a partial space obtained by projecting a cluster in the five-dimensional space onto a three-dimensional space. In a case in which, for example, a predetermined width is added to each element to the centroid as described above, a decision range of "$xc-\alpha<x<xc+\alpha$, $yc-\alpha<y<yc+\alpha$, and $\theta c-\alpha<\theta<\theta c+\alpha$" may be generated.

**[0134]** While the present application has been described with reference to the example embodiments, the present application is not limited to the aforementioned example embodiments. Various changes that may be understood by one skilled in the art may be made to the configurations and the details of the present application within the scope of the present application.

**[0135]** In the aforementioned examples, the program includes instructions (or software codes) that, when loaded into a computer, cause the computer to perform one or more of the functions described in the embodiments. The program may be stored in a non-transitory computer readable medium or a tangible storage medium. By way of example, and not a limitation, non-transitory computer readable media or tangible storage media can include a random-access memory (RAM), a read-only memory (ROM), a flash memory, a solid-state drive (SSD) or other types of memory technologies, a CD-ROM, a digital versatile disc (DVD), a Blu-ray (registered trademark) disc or other types of optical disc storage, and magnetic cassettes, magnetic tape, magnetic disk storage or other types of magnetic storage devices. The program may be transmitted on a transitory computer readable medium or a communication medium. By way of example, and not a limitation, transitory computer readable media or communication media can include electrical, optical, acoustical, or other forms of propagated signals.

**[0136]** From the disclosure thus described, it will be obvious that the embodiments of the disclosure may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the disclosure, and all such modifications as would be obvious to one skilled in the art are intended for inclusion within the scope of the following claims.

What is claimed is:

**1**. A key point correction system comprising:

at least one memory storing instructions; and

at least one processor that executes the instructions to:

acquire a plurality of captured images;

detect a plurality of key points of a moving object from each of the captured images;

decided whether or not the plurality of key points of the moving object detected from the captured images satisfy a predetermined appropriacy condition;

determine, when the plurality of key points of the moving object satisfy the appropriacy condition, a correction parameter to be used to correct the plurality of key points detected for the moving object using the plurality of key points; and

correct, when the correction parameter has been determined for the moving object regarding which the plurality of key points are detected from the captured image, the plurality of key points by using the correction parameter.

**2**. The key point correction system according to claim **1**,

wherein the appropriacy condition indicates a decision range, which is a range that a position, a size, or a posture of the moving object, or a combination of two or more of them is required to satisfy, and

the at least one processor is further configured to:

determine the position, the size, or the posture of the moving object using the plurality of key points of the moving object; and

decide that the appropriacy condition is satisfied when the determined position, size, or posture, or a combination of two or more of them is included in the decision range.

**3**. The key point correction system according to claim **2**,

wherein the at least one processor is further configured to:

compute key point correspondence points on an orthoimage that correspond to the plurality of respective key points by performing orthorectification on the plurality of key points of the moving object detected from the captured images; and

compute the position, the size, or the posture of the moving object on the orthoimage that is determined based on the positions of the plurality of the computed key point correspondence points as the position, the size, or the posture of the moving object.

**4**. The key point correction system according to claim **3**,

wherein the at least one processor is further configured to:

generate the decision range indicated by the appropriacy condition using a plurality of training images in which ground-truth key points regarding the moving object are indicated, and

the generation of the decision range includes:

compute, for each of the plurality of training images, an error between the ground-truth key points in the training image and the key points of the moving object detected from the training image;

compute a feature vector of the key points of the moving object when the error is equal to or smaller than a threshold; and

generate the decision range using feature vectors included in a cluster whose stability is equal to or larger than a threshold among a plurality of clusters obtained by clustering the plurality of the computed feature vectors.

**5**. The key point correction system according to claim **1**, wherein the at least one processor is further configured to:

compute, for the plurality of key points of the moving object, a time stability index value that represents temporal stability; and

decide that the appropriacy condition is satisfied when the time stability index value is equal to or larger than a threshold.

**6**. The key point correction system according to claim **5**, wherein the time stability index value becomes larger as an amount of change over time of a size of the moving object within a predetermined time becomes smaller.

**7**. The key point correction system according to claim **6**, wherein the time stability index value becomes larger as reliability of the plurality of key points of the moving object becomes higher.

**8**. The key point correction system according to claim **1**, wherein the correction parameter represents a size of the moving object, and

the at least one processor is configured to correct, when the correction parameter is determined for the moving object regarding which the plurality of key points are detected from the captured image, one or more of the key points in such a way that the size of the moving object represented by the plurality of key points becomes equal to the size represented by the correction parameter.

**9**. A key point correction method executed by a computer, the key point correction method comprising:

acquiring a plurality of captured images;

detecting a plurality of key points of a moving object from each of the captured images;

deciding whether or not the plurality of key points of the moving object detected from the captured images satisfy a predetermined appropriacy condition;

determining, when the plurality of key points of the moving object satisfy the appropriacy condition, a correction parameter to be used to correct the plurality of key points detected for the moving object using the plurality of key points; and

correcting, when the correction parameter has been determined for the moving object regarding which the plurality of key points are detected from the captured image, the plurality of key points by using the correction parameter.

**10**. A non-transitory computer readable medium storing a program for causing a computer to execute:

acquiring a plurality of captured images;

detecting a plurality of key points of a moving object from each of the captured images;

deciding whether or not the plurality of key points of the moving object detected from the captured images satisfy a predetermined appropriacy condition;

determining, when the plurality of key points of the moving object satisfy the appropriacy condition, a correction parameter to be used to correct the plurality of key points detected for the moving object using the plurality of key points; and

correcting, when the correction parameter has been determined for the moving object regarding which the plurality of key points are detected from the captured image, the plurality of key points by using the correction parameter.

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