

DESCRIPTION

TITLE OF INVENTION: OVERHEAD WIRE FITTING ABNORMALITY DETECTION DEVICE AND OVERHEAD WIRE FITTING ABNORMALITY DETECTION METHOD

TECHNICAL FIELD

[0001] The present invention relates to an overhead wire fitting abnormality detection device and an overhead wire fitting abnormality detection method.

BACKGROUND

[0002] Conventionally, in electric railway equipment, maintenance and inspection work has been carried out for overhead contact line fittings. To carry out maintenance, an inspector visually checks for abnormalities in overhead contact line fittings. Overhead contact line fittings refer to fittings in electric railway equipment used to hold overhead train lines (contact wires, messenger wires, and auxiliary messenger wires; hereinafter “overhead contact line”) for supplying power to vehicles in predetermined positions, or to electrically connect or demarcate multiple overhead contact lines. However, visual inspections have limitations and abnormalities could be missed.

[0003] Therefore, Patent Documents 1 and 2 disclose technology involving generating an input image by capturing an image of an overhead contact line fitting with a line sensor camera mounted on the roof of a railway vehicle and, based on the input image, detecting abnormalities in the overhead contact line fitting using machine learning.

CITATION LIST

PATENT LITERATURE

[0004] Patent Document 1: JP 2020-147129 A

Patent Document 2: JP 2020-149286 A

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0005] However, in Patent Documents 1 and 2, when generating an input image,

image processing is not carried out on the captured input image. Therefore, when there is excess data (fittings outside the target image-capturing range, such as those outside the main line) in the image, such data could affect the abnormality detection accuracy.

[0006] In addition, when capturing images with a narrowed target image-capturing range, there are numerous constraints on equipment installation such as the depth of field and the angle of view of line sensor cameras, as well as the rolling stock gauge of railway vehicles, resulting in a problem where the selection of equipment is significantly limited.

[0007] Therefore, the present invention addresses a problem of providing an overhead contact line fitting abnormality detection device and an overhead contact line fitting abnormality detection method that make it possible to provide a dataset for improving the detection accuracy of abnormalities in overhead contact line fittings.

SOLUTION TO PROBLEM

[0008] An overhead contact line fitting abnormality detection device according to a first aspect for solving the above-mentioned problem includes:

- a first line sensor camera and a second line sensor camera that capture images of an overhead contact line fitting using fisheye lenses while a railway vehicle is running, the first line sensor camera and the second line sensor camera being spaced apart by a predetermined distance on a left side and a right side relative to the direction of travel of the railway vehicle;

- a trimming unit that trims an area outside a target image-capturing range from a first image captured by the first line sensor camera and trims an area outside a target image-capturing range from a second image captured by the second line sensor camera; and

- a horizontal inversion processing unit that horizontally inverts either the first image that was trimmed or the second image that was trimmed such that the orientations of the overhead contact line fitting that were captured match with respect to the center position of the first line sensor camera in the first image and the center position of the second line sensor camera in the second image, and

- from among the first image that was trimmed and the second image that was trimmed, an image that was not horizontally inverted by the horizontal inversion

processing unit and an inverted image obtained by the horizontal inversion processing unit horizontally inverting either the first image that was trimmed or the second image that was trimmed are provided as processed images for detecting abnormalities in the overhead contact line fittings.

[0009] In addition, a second aspect of the present invention for solving the above-mentioned problem is the overhead contact line fitting abnormality detection device according to the first aspect, further including:

- an image left-right splitting processing unit that splits the first image left and right from the center position of the first line sensor camera in the first image and splits the second image left and right from the center position of the second line sensor camera in the second image; and

- an outer-side image removal processing unit that removes, from among split images obtained by splitting the first image, a split image corresponding to an outer side of the railway vehicle from the center position of the first line sensor camera, and removes, from among split images obtained by splitting the second image, a split image corresponding to the outer side of the railway vehicle from the center position of the second line sensor camera, and

- the trimming unit
trims an area outside the target image-capturing range from a first split image remaining without being removed, and trims an area outside the target image-capturing range from a second split image remaining without being removed, and

- the horizontal inversion processing unit
horizontally inverts either the first split image that was trimmed or the second split image that was trimmed such that orientation of the overhead contact line fitting captured in the first split image that was trimmed and orientation of the overhead contact line fitting captured in the second split image that was trimmed match.

[0010] In addition, a third aspect of the present invention for solving the above-mentioned problem is the overhead contact line fitting abnormality detection device according to the first aspect, further including:

- an image left-right splitting processing unit that splits the first image left and right from the center position of the first line sensor camera in the first image and

splits the second image left and right from the center position of the second line sensor camera in the second image, and

the trimming unit

trims an area outside the target image-capturing range from a first left split image and a first right split image obtained by splitting the first image left and right, and trims an area outside the target image-capturing range from a second left split image and a second right split image obtained by splitting the second image left and right, and

the horizontal inversion processing unit

horizontally inverts either the first left split image that was trimmed or the first right split image that was trimmed such that orientations of the overhead contact line fitting in the first left split image and the first right split image that were trimmed match, and horizontally inverts either the second left split image that was trimmed or the second right split image that was trimmed such that orientations of the overhead contact line fitting in the second left split image and the second right split image that were trimmed match.

[0011] In addition, a fourth aspect of the present invention for solving the above-mentioned problem is an overhead contact line fitting abnormality detection method, including:

a step of capturing images of an overhead contact line fitting while a railway vehicle is running using a first line sensor camera and a second line sensor camera which comprise fisheye lenses and which are spaced apart by a predetermined distance on a left side and a right side relative to the direction of travel of the railway vehicle;

a step of trimming an area outside a target image-capturing range from a first image captured by the first line sensor camera and trimming an area outside a target image-capturing range from a second image captured by the second line sensor camera;

a step of horizontally inverting either the first image that was trimmed or the second image that was trimmed such that the orientations of the overhead contact line fitting that were captured match with respect to the center position of the first line sensor camera in the first image and the center position of the second line sensor

camera in the second image; and

a step of, from among the first image that was trimmed and the second image that was trimmed, providing an image that was not horizontally inverted by the step of horizontally inverting and an inverted image obtained by the step of horizontally inverting horizontally inverting either the first image that was trimmed or the second image that was trimmed as processed images for detecting abnormalities in the overhead contact line fittings.

[0012] In addition, a fifth aspect of the present invention for solving the above-mentioned problem is the overhead contact line fitting abnormality detection method according to the fourth aspect, further including:

a step of splitting the first image left and right from the center position of the first line sensor camera in the first image and splitting the second image left and right from the center position of the second line sensor camera in the second image; and

a step of removing, from among split images obtained by splitting the first image, a split image corresponding to an outer side of the railway vehicle from the center position of the first line sensor camera, and removing, from among split images obtained by splitting the second image, a split image corresponding to the outer side of the railway vehicle from the center position of the second line sensor camera, and

the step of trimming an area outside a target image-capturing range

trims an area outside the target image-capturing range from a first split image remaining without being removed, and trims an area outside the target image-capturing range from a second split image remaining without being removed, and

the step of horizontally inverting

horizontally inverts either the first split image that was trimmed or the second split image that was trimmed such that orientation of the overhead contact line fittings captured in the first split image that was trimmed and orientation of the overhead contact line fitting captured in the second split image that was trimmed match.

[0013] In addition, a sixth aspect of the present invention for solving the above-mentioned problem is the overhead contact line fitting abnormality detection method according to the fourth aspect, further including:

a step of splitting the first image left and right from the center position of the first line sensor camera in the first image and splitting the second image left and right from the center position of the second line sensor camera in the second image,

wherein the step of trimming an area outside a target image-capturing range trims an area outside the target image-capturing range from a first left split image and a first right split image obtained by splitting the first image left and right, and trims an area outside the target image-capturing range from a second left split image and a second right split image obtained by splitting the second image left and right, and

the step of horizontally inverting

horizontally inverts either the first left split image that was trimmed or the first right split image that was trimmed such that orientations of the overhead contact line fitting in the first left split image and the first right split image that were trimmed match, and horizontally inverts either the second left split image that was trimmed or the second right split image that was trimmed such that orientations of the overhead contact line fittings in the second left split image and the second right split image that were trimmed match.

EFFECTS OF INVENTION

[0014] The present invention makes it possible to provide a dataset for improving the detection accuracy of abnormalities in overhead contact line fittings.

BRIEF DESCRIPTION OF DRAWINGS

[0015] Fig. 1 is a schematic diagram illustrating the general configuration of an overhead contact line fitting abnormality detection device 1 according to a first embodiment of the present invention.

Fig. 2 is a schematic diagram for explaining the advantages of line sensor cameras 10L and 10R using fisheye lenses in the first embodiment.

Fig. 3 is a flow chart for explaining the operation of the overhead contact line fitting abnormality detection device 1 according to the first embodiment.

Fig. 4 is a conceptual diagram illustrating data transfer for explaining the operation of the overhead contact line fitting abnormality detection device 1 according to the first embodiment.

Fig. 5 is a schematic diagram illustrating the state while image capturing is being performed by the overhead contact line fitting abnormality detection device 1 according to the first embodiment.

Fig. 6 is a schematic diagram illustrating images captured by the overhead contact line fitting abnormality detection device 1 according to the first embodiment.

Fig. 7 is a conceptual diagram for explaining trimming areas according to the first embodiment.

Fig. 8 is a conceptual diagram for explaining trimming areas for a left image 50L and a right image 50R according to the first embodiment.

Fig. 9 is a conceptual diagram illustrating an original image (left image 50L) before trimming and a left trimmed image 51L acquired after trimming according to the first embodiment.

Fig. 10 is a conceptual diagram illustrating a left trimmed image 51L and a right trimmed image 51R after trimming in the first embodiment.

Fig. 11 is a conceptual diagram for explaining the advantages (effects) of performing trimming in training and inference in the first embodiment.

Fig. 12 is a conceptual diagram for explaining a horizontal inversion process according to the first embodiment.

Fig. 13 is a flow chart for explaining the operation of the overhead contact line fitting abnormality detection device 1 according to a second embodiment of the present invention.

Fig. 14 is a conceptual diagram illustrating data transfer for explaining the operation of the overhead contact line fitting abnormality detection device 1 according to the second embodiment.

Fig. 15 is a conceptual diagram for explaining an image left-right splitting process according to the second embodiment.

Fig. 16 is a conceptual diagram for explaining an outer-side image removal process according to the second embodiment.

Fig. 17 is a conceptual diagram for explaining trimming areas for a left split image

54L and a right split image 53R according to the second embodiment.

Fig. 18 is a conceptual diagram illustrating a left trimmed image 55L and a right trimmed image 55R after trimming in the second embodiment.

Fig. 19 is a conceptual diagram illustrating a left trimmed image 55L after trimming and a right inverted image 56R after image inversion in the second embodiment.

Fig. 20 is a flow chart for explaining the operation of the overhead contact line fitting abnormality detection device 1 according to a third embodiment of the present invention.

Fig. 21 is a conceptual diagram illustrating data transfer for explaining the operation of the overhead contact line fitting abnormality detection device 1 according to the third embodiment.

Fig. 22 is a conceptual diagram for explaining an image left-right splitting process according to the third embodiment.

Fig. 23 is a conceptual diagram for explaining trimming areas for left split images 53L and 54L and right split images 53R and 54R according to the third embodiment.

Fig. 24 is a conceptual diagram illustrating left trimmed images 57L and 58L and right trimmed images 57R and 58R after trimming in the third embodiment.

Fig. 25 is a conceptual diagram illustrating a left trimmed inverted image 59L and the left trimmed image 58L, and the right trimmed inverted image 59R and the right trimmed image 58R in the third embodiment.

DESCRIPTION OF EMBODIMENTS

[0016] Below, with reference to the accompanying drawings, embodiments for practicing the present invention are explained.

The present invention aims to attain a reduction in the labor required for maintenance and inspection operations for overhead contact line fittings by enabling automatic detection of overhead contact line fittings for images obtained from at least two line sensor cameras mounted on the roof of a railway vehicle and detecting abnormalities in overhead contact line fittings based on captured images through subsequent processing.

[0017] A. First Embodiment

Fig. 1 is a schematic diagram illustrating the general configuration of an overhead contact line fitting abnormality detection device 1 according to the first embodiment of the present invention. In Fig. 1, two line sensor cameras (first and second line sensor cameras) 10L and 10R equipped with fisheye lenses are installed at a predetermined distance from each other in the vehicle width direction on a vehicle roof 21 of a railway vehicle 2 and a plurality of lighting units 11, 11, and 11 is installed facing upward. The line sensor cameras 10L and 10R are installed such that the angle of view is oriented in the vertical direction relative to the vehicle roof 21. The line sensor cameras 10L and 10R capture images of overhead contact line fittings installed along the railway tracks above the vehicle roof 21.

[0018] In the present invention, overhead contact line fittings refer to:

- Hangers, droppers, connectors, double ears
- Pull-off arms, supports

These fittings can be detected by the overhead contact line fitting abnormality detection device and the overhead contact line fitting abnormality detection method according to the present invention.

[0019] An image processing device (hereinafter referred to as on-board PC) 12 such as a personal computer is mounted in a railway vehicle 2. The on-board PC 12 is provided with a data storage unit 13 that stores images captured by the line sensor cameras 10L and 10R and an image processing unit 14 that carries out various image processing for captured images and performs preprocessing for detection of overhead contact line fittings and detection of abnormalities (deformation of fittings, presence or absence of screws, and the like) in the overhead contact line fittings based on machine learning.

[0020] In the present invention, the image processing unit 14 is provided with a computing device implementing an artificial intelligence function trained using images of overhead contact line fittings and images of objects other than overhead contact line fittings that were obtained in advance. On the basis of images generated by the aforementioned preprocessing, the image processing unit 14 detects

overhead contact line fittings within the images and detects abnormalities in the overhead contact line fittings that were detected. However, the processing for detecting overhead contact line fittings within an image by the computing device and the processing for detecting abnormalities (deformation of fittings, presence or absence of screws, and the like) in the overhead contact line fittings that were detected are well known. Thus, explanations thereof will be omitted.

[0021] Here, the reason (effect) for using a fisheye lens instead of a wide-angle lens for the line sensor cameras 10L and 10R in the present invention will be explained. Fig. 2(a) and 2(b) are schematic diagrams for explaining the advantages of the line sensor cameras 10L and 10R using fisheye lenses in the first embodiment. Fig. 2(a) illustrates a camera image-capturing range 31, a target image-capturing range 32, and a depth of field 33 in the case of a line sensor camera 30 using a wide-angle lens. In addition, Fig. 2(b) illustrates a camera image-capturing range 34 and a target image-capturing range 35 in the case of the line sensor camera 10L using a fisheye lens. In addition, in Figs. 2(a) and 2(b), a rolling stock gauge 36 is set around the vehicle. The rolling stock gauge 36 is a standard for restricting the numerical values of the width, height, and the like of vehicles such that the vehicles can safely run on the railway tracks. Structures cannot be installed beyond the rolling stock gauge. Although the line sensor camera 10R is not illustrated in Fig. 2(b), the camera image-capturing range 34 would simply be shifted in the lateral direction and the reason (effect) for using a fisheye lens is the same as that for the line sensor camera 10L.

[0022] In the case of a line sensor camera 30 using a wide-angle lens, due to the angle of view of the wide-angle lens, the line sensor camera 30 must be installed obliquely as illustrated by the camera image-capturing range 31 in Fig. 2(a). In this case, because images are captured from a direction oblique to the rectangular target image-capturing range 32, it becomes necessary to set a deep depth of field. In addition, when a wide-angle lens is used, it becomes necessary to install the line sensor camera 30 on an edge of the vehicle roof 21, which may conflict with the above-mentioned rolling stock gauge 36.

[0023] On the other hand, as illustrated in Fig. 2(b), when a fisheye lens is used, the angle of view of the line sensor camera 10L is 180°, as illustrated by the camera

image-capturing range 34, and the fisheye lens is characterized by a deep depth of field. When a fisheye lens is used, it is no longer necessary to consider the angle of view of the line sensor camera 10L. In addition, one of the characteristics of fisheye lenses is a deep depth of field, which makes it possible to capture images with a wide camera image-capturing range 34 compared to a line sensor camera 30 using a wide-angle lens. Thus, the use of fisheye lenses in the line sensor cameras 10L and 10R eliminates the need for installation on an edge of the vehicle roof 21 and makes it possible to significantly reduce installation constraints.

[0024] Fig. 3 is a flow chart for explaining the operation of the overhead contact line fitting abnormality detection device 1 according to the first embodiment. In addition, Fig. 4 is a conceptual diagram illustrating data transfer for explaining the operation of the overhead contact line fitting abnormality detection device 1 according to the first embodiment. In addition, Fig. 5 is a schematic diagram illustrating the state while image capturing is being performed by the overhead contact line fitting abnormality detection device 1 according to the first embodiment. In addition, Fig. 6 is a schematic diagram illustrating images captured by the overhead contact line fitting abnormality detection device 1 according to the first embodiment.

[0025] In the first embodiment, the processes in steps S10 to S16 below are repeated for a plurality of images (corresponding to the number of images) captured by line sensor cameras at a predetermined time interval from the start to the end of image capturing.

[0026] <Image-Capturing Process>

First, the overhead contact line fitting abnormality detection device 1 captures images by means of the line sensor cameras 10L and 10R while the vehicle is running (step S10). The images captured by the line sensor cameras 10L and 10R are stored in the data storage unit 13, as illustrated in Fig. 4.

[0027] Here, Fig. 5 is a schematic diagram illustrating the positional relationship between the vehicle roof 21, the line sensor cameras 10L and 10R, and the overhead contact lines A to C in the present embodiment. During image capturing, the positional relationship between the vehicle roof 21, the line sensor cameras 10L and 10R, and the overhead contact lines A to C is as illustrated in Fig. 5. The overhead

contact line A is constituted by a contact wire 40A, a messenger wire 41A suspending the contact wire 40A, and an overhead contact line fitting 42A for coupling the contact wire 40A and the messenger wire 41A. The overhead contact line B is constituted by a contact wire 40B, a messenger wire 41B suspending the contact wire 40B, and an overhead contact line fitting 42B for coupling the contact wire 40B and the messenger wire 41B. The overhead contact lines A and B are included in the target image-capturing range 35 based on the line sensor cameras 10L and 10R. Moreover, the overhead contact line fittings 42A and 42B of the overhead contact lines A and B included in the target image-capturing range 35 are targets for abnormality detection. On the other hand, an overhead contact line fitting 42C of an overhead contact line C not included in the target image-capturing range 35 is a fitting exempt from image capturing and not subject to abnormality detection.

[0028] When images of overhead contact lines A and B at positions as illustrated in Fig. 5 are captured by the line sensor cameras 10L and 10R, a left image (first image) 50L and a right image (second image) 50R as illustrated in Fig. 6 are captured. The line sensor camera 10L captures the left image 50L illustrated in the upper part of Fig. 6 and the line sensor camera 10R captures the right image 50R illustrated in the lower part of Fig. 6. In Fig. 6, the lateral direction in the left image 50L and the right image 50R corresponds to the lateral direction of the vehicle roof 21. In other words, the images are captured with a lateral offset corresponding to the difference in placement positions between the line sensor camera 10R and the line sensor camera 10L.

[0029] In the left image 50L captured by the line sensor camera 10L, the overhead contact line A is captured on the left side of the camera center and the overhead contact line B is captured on the right side of the camera center. At this time, because the line sensor camera 10L is oriented vertically, the upper portions of overhead contact line fittings 42A1 and 42A2 of the overhead contact line A and the upper portions of overhead contact line fittings 42B1 and 42B2 of the overhead contact line B are captured so as to be positioned closer to the camera center. In addition, in the right image 50R captured by the line sensor camera 10R, the overhead contact lines A and B are captured on the left side of the camera center and the overhead contact line C is captured on the right side of the camera center. At this time, because the line

sensor camera 10R is oriented vertically, the upper portions of overhead contact line fittings 42B1 and 42B2 of the overhead contact line B and the upper portions of overhead contact line fittings 42C1 and 42C2 of the overhead contact line C are captured so as to be positioned closer to the camera center. The overhead contact line fittings 42C1 and 42C2 of the overhead contact line C are not subject to abnormality detection, and are therefore preferably not included in the data for machine learning. These fittings are removed by means of trimming described below.

[0030] <Trimming Process>

Next, the overhead contact line fitting abnormality detection device 1 performs trimming of areas outside the target image-capturing ranges for the captured images (left image 50L, right image 50R) by means of the image processing unit 14 (step S12). More specifically, as illustrated in Fig. 4, the image processing unit 14 trims the captured images (left image 50L, right image 50R) stored in the data storage unit 13 by means of a unit for trimming areas outside the target image-capturing range (trimming unit) 141 to remove image portions outside the target image-capturing ranges, and stores the images that have been trimmed (hereinafter referred to as trimmed images) in the data storage unit 13. The trimming of areas outside the target image-capturing range is for cutting off portions of images of the overhead contact line C, which is outside the target image-capturing range and not subject to abnormality detection. By reducing excess data, the machine learning and inference processing load can be eased.

[0031] Here, Fig. 7 is a conceptual diagram for explaining trimming areas according to the first embodiment. Fig. 7 only explains the line sensor camera 10L, but the same applies to the line sensor camera 10R. In addition, Fig. 8 is a conceptual diagram for explaining trimming areas for the left image 50L and the right image 50R according to the first embodiment.

[0032] Trimming areas are determined based on the relationship between the positions of the line sensor cameras 10L and 10R (hereinafter simply referred to as camera positions) and the target image-capturing range 35. To examine the relationship between the camera positions and the target image-capturing range 35, the positional relationship between areas unnecessary for image capture and pixel

positions in the actual image is checked. In the checking of the positional relationship, as illustrated in Fig. 7, markers (such as white markers) 61L and 62L are placed at the left and right edges at a lowest height 60 of a target image-capturing range 35L, and the pixel positions at which the markers appear in the actual image are checked. The lower part of Fig. 7 illustrates trimming areas 63L and 64L and the target image-capturing range 35L in the left image 50L, and trimming areas 63R and 64R and a target image-capturing range 35R in the right image 50R. The areas outside the pixel positions of the markers 61L and 62L and markers 61R and 62R become the trimming regions 63L and 64L and trimming regions 63R and 64R that are trimmed. Applying this to the captured left image 50L and right image 50R illustrated in Fig. 6, trimming is performed on the left image 50L using the trimming regions 63L and 64L, and on the right image 50R using trimming regions 63R and 64R, as illustrated in Fig. 8.

[0033] Fig. 9 is a conceptual diagram illustrating an original image (left image 50L) before trimming and a left trimmed image 51L after trimming according to the first embodiment. Fig. 9 illustrates the left image 50L as the original image and the left trimmed image (first image that was trimmed) 51L obtained by trimming the left image 50L. The same is true for the right image 50R. As illustrated in Fig. 9, in the original image immediately after capture, that is, the left image 50L, the overhead contact line fittings 42A1 and 42A2 of the overhead contact line A and the overhead contact line fittings 42B1 and 42B2 of the overhead contact line B, which are data for training and inference, and the overhead contact line fittings 42C1 and 42C2 of the overhead contact line C, which are non-target data not for training and inference, are mixed together with identical shapes. In contrast, in the left trimmed image 51L after trimming, parts of the overhead contact line fittings 42C1 and 42C2 of the overhead contact line C, which are non-target data not for training and inference, have been trimmed and cut off.

[0034] Fig. 10 is a conceptual diagram illustrating the left trimmed image 51L and the right trimmed image 51R after trimming in the first embodiment. As illustrated in Fig. 10, by trimming, part of the overhead contact line C, which is non-target data not for training and inference, is trimmed and cut off in both the left trimmed image 51L and the right trimmed image (second image that was trimmed) 51R. This makes it

possible to distinguish the overhead contact line fittings 42A1 and 42A2 of the overhead contact line A and the overhead contact line fittings 42B1 and 42B2 of the overhead contact line B, which are data for training and inference, from the overhead contact line fittings 42C1 and 42C2 of the overhead contact line C, which are non-target data not for training and inference, as different shapes in the left trimmed image 51L.

[0035] In addition to this, it also becomes possible to retain more image features during image compression. In machine learning, for processing convenience, images are resized to a square before performing training and inference. In the first embodiment, trimming the width of the images makes it possible to reduce unnecessary information, and when the images are resized to a square, it becomes possible to perform efficient training and inference.

[0036] Fig. 11 is a conceptual diagram for explaining the advantages (effects) of performing trimming in training and inference in the first embodiment. Fig. 11 illustrates the left image 50L as the original image and the left trimmed image 51L obtained by trimming the left image 50L. The same is true for the right image 50R. The top part of Fig. 11 illustrates image A, which is an enlarged image of the overhead contact line fitting portion when the left image 50L that has not been trimmed has been resized to a square to facilitate efficient training and inference. The bottom part of Fig. 11 illustrates image B, which is an enlarged view of the overhead contact line fitting portion when the left trimmed image 51L after trimming has been resized to a square. As can be seen by comparing image A and image B, in the first embodiment, resizing the left trimmed image 51L to a square makes it possible to retain more fitting information (high-resolution image; coil-shaped fitting has wide spacing) than when the left image 50L before trimming is resized to a square. That is, data loss due to compression can be reduced.

[0037] <Horizontal Inversion Process>

Next, the overhead contact line fitting abnormality detection device 1 horizontally inverts the right trimmed image 51R after trimming (step S14). More specifically, as illustrated in Fig. 4, the image processing unit 14 horizontally inverts the right trimmed image 51R after trimming stored in the data storage unit 13 by means of an image horizontal inversion processing unit 142, and stores the image as a right

inverted image 52R in the data storage unit 13.

[0038] In the right image 50R, which is the original image, the upper portion of the overhead contact line fitting 42B of the overhead contact line B is captured closer to the center of the image due to the installation position of the line sensor camera 10R, as illustrated in Fig. 6 mentioned above. In machine learning, in addition to the shape of the overhead contact line fittings, pixel information in the image also affects accuracy. Thus, overhead contact line fittings at the same positions are desirably captured in the same orientation in the left and right images. However, as illustrated in Fig. 10 mentioned above, in the left trimmed image 51L and the right trimmed image 51R after trimming, the trimming areas differ between the left and right, resulting in differences in the orientations of overhead contact line fittings depending on the positions of the fittings in the left and right images. In the example in Fig. 10, the orientations of the overhead contact line fittings 42B1 and 42B2 differ between the left trimmed image 51L and the right trimmed image 51R. As a result, a situation arises where the image coordinate information and the orientation information regarding the overhead contact line fittings 42B1 and 42B2 do not match. To prevent this, from among the left trimmed image 51L and the right trimmed image 51R after trimming, the right trimmed image 51R is subjected to a horizontal inversion process.

[0039] Fig. 12 is a conceptual diagram for explaining a horizontal inversion process according to the first embodiment. As illustrated in Fig. 12, when the right trimmed image 51R is subjected to a horizontal inversion process, the camera center positions in the left trimmed image 51L and the right inverted image (inverted image) 52R are brought into conformity, such that, relative to the left and right camera centers, the upper portions of the overhead contact line fittings 42A1 and 42A2 in the left image are always located on the right, and the upper portions of the overhead contact line fittings 42A1, 42A2, 42B1, and 42B2 in the right image are always located on the left. Consequently, the relationship between the positional relationship in terms of the pixels in the images and the orientations of the overhead contact line fittings 42B1 and 42B2 is also brought into conformity and the accuracy of machine learning can also be improved.

[0040] <Processed Image Provision Process>

Next, the overhead contact line fitting abnormality detection device 1 supplies the left

trimmed image 51L after trimming and the right inverted image 52R after the horizontal inversion process to a machine learning system (computing device) not shown as processed images (step S16). On the basis of the left trimmed image 51L after trimming and the right inverted image 52R after the horizontal inversion process, which are processed images, the machine learning system not shown performs machine learning and detects abnormalities (deformation of fittings, presence or absence of screws, and the like) in the overhead contact line fittings.

[0041] According to the aforementioned first embodiment, trimming makes it possible to reduce unnecessary data and thereby ease the processing load on training and inference. In addition, trimming also makes it possible to mitigate the loss of overhead contact line fitting information when resizing to a square. In addition, image inversion makes it possible to bring the relationship between the positional relationship in terms of the pixels in the images and the orientations of the overhead contact line fittings into conformity and thereby improve the accuracy of machine learning. Moreover, these effects make it possible to improve the accuracy when detecting abnormalities in overhead contact line fittings.

[0042] B. Second Embodiment

Next, the second embodiment of the present invention is explained.

The configuration of the overhead contact line fitting abnormality detection device 1 is the same as that in Fig. 1. Thus, explanations thereof will be omitted. Fig. 13 is a flow chart for explaining the operation of the overhead contact line fitting abnormality detection device 1 according to the second embodiment. In addition, Fig. 14 is a conceptual diagram illustrating data transfer for explaining the operation of the overhead contact line fitting abnormality detection device 1 according to the second embodiment. The same reference signs are used for the portions corresponding to Fig. 4, and explanations thereof will be omitted.

[0043] In the second embodiment, the processes in steps S20 to S30 are repeated for a plurality of images (corresponding to the number of images) captured by line sensor cameras at a predetermined time interval from the start to the end of image capturing.

[0044] <Image-Capturing Process>

First, the overhead contact line fitting abnormality detection device 1 captures images by means of the line sensor cameras 10L and 10R while the vehicle is running (step S20). More specifically, the images captured by the line sensor cameras 10L and 10R are stored in the data storage unit 13, as illustrated in Fig. 14. As illustrated in Fig. 6 mentioned above, the captured images are the left image 50L captured by the line sensor camera 10L and the right image 50R captured by the line sensor camera 10R.

[0045] <Image Left-Right Splitting Process>

Next, the overhead contact line fitting abnormality detection device 1 performs a splitting process by means of the image processing unit 14 to split each of the captured images (left image 50L, right image 50R) at the camera center into left and right images (step S22). More specifically, as illustrated in Fig. 14, the image processing unit 14 splits the captured images (left image 50L and right image 50R) stored in the data storage unit 13 at the respective camera centers thereof into left and right images by means of an image left-right splitting processing unit 143 and stores each image as a split image in the data storage unit 13. Here, Fig. 15 is a conceptual diagram for explaining an image left-right splitting process according to the second embodiment. As illustrated in Fig. 15, each of the left image 50L and the right image 50R is split at the camera center into left and right images, resulting in left split images (images resulting from splitting) 53L and 54L and right split images (images resulting from splitting) 53R and 54R.

[0046] <Outer-Side Image Removal Process>

Next, the overhead contact line fitting abnormality detection device 1 removes, from the left and right split images, the portions of the images corresponding to the sections on the outer side of the vehicle from the camera center (step S24). More specifically, as illustrated in Fig. 14, the image processing unit 14 removes, from among the left split images and the right split images stored in the data storage unit 13, the images of the sections corresponding to the outer side of the vehicle from the camera center by means of an outer-side image removal processing unit 144, and stores the remaining left split image and the right split image in the data storage unit 13.

[0047] Fig. 16 is a conceptual diagram for explaining an outer-side image removal process according to the second embodiment. As illustrated in the top part of Fig. 16, from among the left split images (split images obtained by splitting the first image) 53L and 54L, the left split image (image corresponding to the outer side) 53L corresponding to the outer side of the vehicle from the camera center is removed, and from among the right split images (split images obtained by splitting the second image) 53R and 54R, the right split image (image corresponding to the outer side) 54R corresponding to the outer side of the vehicle from the camera center is removed. In other words, for the left image 50L, the left split image 54L, which is the right half, is retained, and for the right image 50R, the right split image 53R, which is the left half, is retained.

[0048] Generally, most overhead contact line fittings are installed near the center of the vehicle (the position of the overhead contact line B in Figs. 5 and 6). In addition, as discussed above, the upper portions of the overhead contact line fittings 42A and 42B are captured in such a manner as to be positioned at the center of the images, as illustrated in Fig. 6. Accordingly, in order to bring the vertical orientation of the overhead contact line fittings 42A and 42B in the images into conformity, the images of the sections corresponding to the outer side of the vehicle from the camera center (the side where the overhead contact line B is not shown), where there are relatively fewer overhead contact line fittings to be captured, are removed. As a result, although an area arises in which abnormality detection, which was conventionally performed with the left and right line sensor cameras 10L and 10R, is performed with only the line sensor camera 10R, as illustrated in the lower part of Fig. 16, it becomes possible to completely bring the orientations of the overhead contact line fittings within one original image into conformity.

[0049] In the example in Fig. 16, with respect to the line sensor camera 10L, the orientations of the overhead contact line fittings 42B1, 42B2, 42C1, and 42C2 of the overhead contact lines B and C in the left split image 54L match, and with respect to the line sensor camera 10R, the orientations of the overhead contact line fittings 42A1, 42A2, 42B1, and 42B2 of the overhead contact lines A and B in the right split image 53R match. Moreover, in this case, abnormalities are detected only with the line sensor camera 10R for the overhead contact line fittings 42A1 and 42A2 of the

overhead contact line A. In addition, abnormalities are detected with both the left and right line sensor cameras 10L and 10R for the overhead contact line fittings 42B1 and 42B2 of the overhead contact line B. In addition, in this case, although there are no overhead contact lines at the right end in the target image-capturing range, if one were to be present, abnormalities would be detected only with the line sensor camera 10L.

[0050] <Trimming Process>

Next, similar to the aforementioned first embodiment, the overhead contact line fitting abnormality detection device 1 performs trimming of areas outside the target image-capturing ranges for the left split image 54L and the right split image 53R after left-right splitting and removal of outer-side images by means of the image processing unit 14 (step S26). More specifically, as illustrated in Fig. 14, the image processing unit 14, by means of the unit for trimming areas outside the target image-capturing range 141, performs trimming of areas outside the target image-capturing ranges for the left split image and the right split image, from which the outer-side images have been removed and which are stored in the data storage unit 13, and stores the images as a left trimmed image and a right trimmed image in the data storage unit 13.

[0051] Fig. 17 is a conceptual diagram for explaining trimming areas for the left split image 54L and the right split image 53R according to the second embodiment. The trimming process is essentially the same as that in the aforementioned first embodiment. The trimming areas according to the second embodiment are two locations: a trimming area (outside the target image-capturing range) 64L at the right end of the left split image 54L, and a trimming area (outside the target image-capturing range) 64R at the left end of the right split image 53R.

[0052] Fig. 18 is a conceptual diagram illustrating a left trimmed image 55L and a right trimmed image 55R after trimming in the second embodiment. By trimming the left split image (first split image) 54L and the right split image (second split image) 53R, it is possible to cut off a portion of the image of the overhead contact line C that is outside the target image-capturing range and not subject to abnormality detection, as illustrated in Fig. 18.

[0053] <Image Inversion Process>

Next, similar to the aforementioned first embodiment, the overhead contact line fitting abnormality detection device 1 horizontally inverts the right trimmed image 55R after trimming by means of the image processing unit 14 (step S28). More specifically, as illustrated in Fig. 14, the image processing unit 14 horizontally inverts the right trimmed image after trimming stored in the data storage unit 13 by means of the image horizontal inversion processing unit 142, and stores the image as a right inverted image in the data storage unit 13.

[0054] Fig. 19 is a conceptual diagram illustrating the left trimmed image 55L after trimming and a right inverted image 56R after image inversion in the second embodiment. The top part of Fig. 19 illustrates the left trimmed image 55L after trimming that was obtained from the image captured by the line sensor camera 10L on the left side. The bottom part of Fig. 19 illustrates the right inverted image 56R that has been subjected to the trimming and inversion processes. In the second embodiment as well, by horizontally inverting the right trimmed image 55R after trimming, the orientations of the overhead contact line fittings 42B1 and 42B2 of the overhead contact line B in the left trimmed image 55L and the orientations of the overhead contact line fittings 42A1 and 42A2 of the overhead contact line A and the overhead contact line fittings 42B1 and 42B2 of the overhead contact line B in the right inverted image 56R are brought into conformity, as illustrated in Fig. 19. This also makes it possible to improve the accuracy of machine learning.

[0055] <Processed Image Provision Process>

Next, the overhead contact line fitting abnormality detection device 1 supplies the left trimmed image 55L after trimming and the right inverted image 56R that has been subjected to the trimming and inversion processes to a machine learning system (computing device) not shown as processed images (step S30). On the basis of the left trimmed image 55L after trimming and the right inverted image 56R that has been subjected to the trimming and inversion processes, which are processed images, the machine learning system not shown performs machine learning and detects abnormalities (deformation of fittings, presence or absence of screws, and the like) in the overhead contact line fittings.

[0056] According to the aforementioned second embodiment, compared to the first embodiment, it is possible to completely bring the orientations of the overhead contact line fittings into conformity and thereby further improve the accuracy of machine learning. In addition, it is also possible to mitigate the loss of overhead contact line fitting information when resizing to a square. In addition, the outer-side image removal process makes it possible to further reduce unnecessary data and thereby further ease the processing for training and inference.

[0057] C. Third Embodiment

Next, the third embodiment of the present invention is explained.

The configuration of the overhead contact line fitting abnormality detection device 1 is the same as that in Fig. 1. Thus, explanations thereof will be omitted. Fig. 20 is a flow chart for explaining the operation of the overhead contact line fitting abnormality detection device 1 according to the third embodiment. In addition, Fig. 21 is a conceptual diagram illustrating data transfer for explaining the operation of the overhead contact line fitting abnormality detection device 1 according to the third embodiment. The same reference signs are used for the portions corresponding to Fig. 14, and explanations thereof will be omitted.

[0058] In the third embodiment, the processes in steps S40 to S48 are repeated for a plurality of images (corresponding to the number of images) captured by line sensor cameras at a predetermined time interval from the start to the end of image capturing.

[0059] <Image-Capturing Process>

First, the overhead contact line fitting abnormality detection device 1 captures images of overhead contact line fittings by means of the line sensor cameras 10L and 10R while the vehicle is running (step S40). More specifically, the images captured by the line sensor cameras 10L and 10R are stored in the data storage unit 13, as illustrated in Fig. 21. As illustrated in Fig. 6 mentioned above, the captured images are the left image 50L captured by the line sensor camera 10L and the right image 50R captured by the line sensor camera 10R.

[0060] <Image Left-Right Splitting Process>

Next, similar to the second embodiment, the overhead contact line fitting abnormality detection device 1 performs a splitting process by means of the image processing unit 14 to split each of the captured images (left image 50L, right image 50R) at the camera center into left and right images (step S42). More specifically, as illustrated in Fig. 21, the image processing unit 14 splits the captured images (left image 50L and right image 50R) stored in the data storage unit 13 at the respective camera centers thereof into left and right images by means of the image left-right splitting processing unit 143 and stores the images as left and right split images in the data storage unit 13.

[0061] Fig. 22 is a conceptual diagram for explaining the image left-right splitting process according to the third embodiment. As illustrated in Fig. 22, each of the left image 50L and the right image 50R is split at the camera center into left and right images, resulting in left split images (first left split image, first right split image) 53L and 54L and right split images (second left split image, second right split image) 53R and 54R.

[0062] <Trimming Process>

Next, similar to the aforementioned first and second embodiments, the overhead contact line fitting abnormality detection device 1, by means of the image processing unit 14, performs trimming of areas outside the target image-capturing ranges for the left split images 53L and 54L and the right split images 53R and 54R after left-right splitting (step S44). More specifically, as illustrated in Fig. 21, the image processing unit 14, by means of the unit for trimming areas outside the target image-capturing range 141, performs trimming of areas outside the target image-capturing ranges for the left split images and the right split images, which are stored in the data storage unit 13, and stores the images as trimmed images after trimming in the data storage unit 13.

[0063] Fig. 23 is a conceptual diagram for explaining trimming areas for the left split images 53L and 54L and the right split images 53R and 54R according to the third embodiment. The trimming process is essentially the same as that in the aforementioned first embodiment. The trimming areas according to the trimming process of the third embodiment are four locations: a trimming area 63L at the left end of the left split image 53L and a trimming area 64L at the right end of the left split

image 54L, as well as a trimming area 63R at the left end of the right split image 53R and a trimming area 64R at the right end of the right split image 54R.

[0064] Fig. 24 is a conceptual diagram illustrating left trimmed images 57L and 58L and right trimmed images 57R and 58R after trimming in the third embodiment. As illustrated in Fig. 24, by trimming the left end of the left split image 53L and the right end of the left split image 54L, as well as the left end of the right split image 53R and the right end of the right split image 54R, it is possible to cut off portions of the images of the overhead contact line C that is outside the target image-capturing ranges and not subject to abnormality detection.

[0065] <Image Inversion Process>

Next, similar to the aforementioned first and second embodiments, the overhead contact line fitting abnormality detection device 1, by means of the image processing unit 14, horizontally inverts a portion of the images after splitting and trimming, that is, the left trimmed image 57L and the right trimmed image 57R (step S28). More specifically, as illustrated in Fig. 21, the image processing unit 14 horizontally inverts the left trimmed image and the right trimmed image after splitting and trimming stored in the data storage unit 13 by means of the image horizontal inversion processing unit 142, and stores each image as a left trimmed image and a right trimmed image in the data storage unit 13.

[0066] Fig. 25 is a conceptual diagram illustrating a left trimmed inverted image 59L and the left trimmed image 58L, and a right trimmed inverted image 59R and the right trimmed image 58R in the third embodiment. The top part of Fig. 25 illustrates the left trimmed image 58L after trimming and the left trimmed inverted image 59L that was trimmed and then further subjected to an inversion process, as well as the right trimmed image 58R after trimming and the right trimmed inverted image 59R that was trimmed and then further subjected to an inversion process. In the third embodiment as well, as illustrated in Fig. 25, the orientations of the overhead contact line fittings 42A1 and 42A2 of the overhead contact line A in the left trimmed inverted image 59L, the orientations of the overhead contact line fittings 42B1 and 42B2 of the overhead contact line B in the left trimmed image 58L, and the orientations of the overhead contact line fittings 42A1 and 42A2 of the overhead contact line A and the orientations of the overhead contact line fittings 42B1 and 42B2 of the overhead

contact line B in the right trimmed inverted image 59R are all brought into conformity. As a result, it is also possible to improve the accuracy of machine learning. If there are no overhead contact line fittings subject to detection within an image, as in the right trimmed image 58R in Fig. 25, the image is not used in the training dataset.

[0067] <Processed Image Provision Process>

Next, the overhead contact line fitting abnormality detection device 1 supplies the left trimmed inverted image 59L and the left trimmed image 58L, as well as the right trimmed inverted image 59R and the right trimmed image 58R, to a machine learning system (computing device) not shown as processed images (step S48). On the basis of the left trimmed inverted image 59L and the left trimmed image 58L as well as the right trimmed inverted image 59R, which are processed images, the machine learning system not shown performs machine learning and detects abnormalities (deformation of fittings, presence or absence of screws, and the like) in the overhead contact line fittings.

[0068] The overhead contact line fitting abnormality detection device and the overhead contact line fitting abnormality detection method according to the present embodiment configured in this manner make it possible to improve the detection accuracy of abnormalities in overhead contact line fittings. In addition, reducing the data volume through trimming makes it possible to ease the load on machine learning and inference processing. Furthermore, by using fisheye lenses in the line sensor cameras 10L and 10R, it becomes possible to achieve an equipment configuration that is less susceptible to installation conditions.

[0069] In the aforementioned first to third embodiments, the right image was inverted, but the invention is not limited to such a configuration. Either image may be inverted such that the orientations of the overhead contact line fittings match with respect to the camera center.

[0070] In addition to the above, configurations described in the embodiments above may be selectively added or removed, or appropriately modified to other configurations, so long as such changes do not depart from the spirit of the present invention.

REFERENCE SIGNS LIST

[0071]

1	Overhead contact line fitting abnormality detection device
2	Railway vehicle
21	Vehicle roof
10L, 10R	Line sensor cameras
11, 11, 11	Lighting units
12	On-board PC
13	Data storage unit
14	Image processing unit
141	Unit for trimming areas outside the target image-capturing range
142	Image horizontal inversion processing unit
143	Image left-right splitting processing unit
144	Outer-side image removal processing unit
A to C	Overhead contact lines
40A to 40C	Contact wires
41A to 41C	Messenger wires
42A to 42C	Overhead contact line fittings
42A1, 42A2, 42B1, 42B2, 42C1, 42C2	Overhead contact line fittings
51L	Left trimmed image
51R	Right trimmed image
52R	Right inverted image
53L, 54L	Left split images
53R, 54R	Right split images

CLAIMS

1. An overhead contact line fitting abnormality detection device, comprising:
 - a first line sensor camera and a second line sensor camera that capture images of an overhead contact line fitting using fisheye lenses while a railway vehicle is running, the first line sensor camera and the second line sensor camera being spaced apart by a predetermined distance on a left side and a right side relative to a direction of travel of the railway vehicle;
 - a trimming unit that trims an area outside a target image-capturing range from a first image captured by the first line sensor camera and trims an area outside a target image-capturing range from a second image captured by the second line sensor camera; and
 - a horizontal inversion processing unit that horizontally inverts either the first image that was trimmed or the second image that was trimmed such that orientations of the overhead contact line fitting that were captured match with respect to a center position of the first line sensor camera in the first image and a center position of the second line sensor camera in the second image,wherein, from among the first image that was trimmed and the second image that was trimmed, the overhead contact line fitting abnormality detection device provides an image that was not horizontally inverted by the horizontal inversion processing unit and an inverted image obtained by the horizontal inversion processing unit horizontally inverting either the first image that was trimmed or the second image that was trimmed as processed images for detecting an abnormality in the overhead contact line fittings.
2. The overhead contact line fitting abnormality detection device according to claim 1, further comprising:
 - an image left-right splitting processing unit that splits the first image left and right from the center position of the first line sensor camera in the first image and splits the second image left and right from the center position of the second line sensor camera in the second image; and
 - an outer-side image removal processing unit that removes, from among split images obtained by splitting the first image, a split image corresponding to an outer side of the railway vehicle from the center position of the first line sensor camera, and

removes, from among split images obtained by splitting the second image, a split image corresponding to the outer side of the railway vehicle from the center position of the second line sensor camera,

wherein the trimming unit

trims an area outside the target image-capturing range from a first split image remaining without being removed, and trims an area outside the target image-capturing range from a second split image remaining without being removed, and

the horizontal inversion processing unit

horizontally inverts either the first split image that was trimmed or the second split image that was trimmed such that orientation of the overhead contact line fitting captured in the first split image that was trimmed and orientation of the overhead contact line fitting captured in the second split image that was trimmed match.

3. The overhead contact line fitting abnormality detection device according to claim 1, further comprising:

an image left-right splitting processing unit that splits the first image left and right from the center position of the first line sensor camera in the first image and splits the second image left and right from the center position of the second line sensor camera in the second image,

wherein the trimming unit

trims an area outside the target image-capturing range from a first left split image and a first right split image obtained by splitting the first image left and right, and trims an area outside the target image-capturing range from a second left split image and a second right split image obtained by splitting the second image left and right, and

the horizontal inversion processing unit

horizontally inverts either the first left split image that was trimmed or the first right split image that was trimmed such that orientations of the overhead contact line fitting in the first left split image and the first right split image that were trimmed match, and horizontally inverts either the second left split image that was trimmed or the second right split image that was trimmed such that orientations of the overhead contact line fitting in the second left split image and the second right split image that were trimmed match.

4. An overhead contact line fitting abnormality detection method, comprising:
- a step of capturing images of an overhead contact line fitting while a railway vehicle is running using a first line sensor camera and a second line sensor camera which comprise fisheye lenses and which are spaced apart by a predetermined distance on a left side and a right side relative to a direction of travel of the railway vehicle;
 - a step of trimming an area outside a target image-capturing range from a first image captured by the first line sensor camera and trimming an area outside a target image-capturing range from a second image captured by the second line sensor camera;
 - a step of horizontally inverting either the first image that was trimmed or the second image that was trimmed such that orientations of the overhead contact line fitting that were captured match with respect to a center position of the first line sensor camera in the first image and a center position of the second line sensor camera in the second image; and
 - a step of, from among the first image that was trimmed and the second image that was trimmed, providing an image that was not horizontally inverted by the step of horizontally inverting and an inverted image obtained by the step of horizontally inverting horizontally inverting either the first image that was trimmed or the second image that was trimmed as processed images for detecting an abnormality in the overhead contact line fittings.
5. The overhead contact line fitting abnormality detection method according to claim 4, further comprising:
- a step of splitting the first image left and right from the center position of the first line sensor camera in the first image and splitting the second image left and right from the center position of the second line sensor camera in the second image; and
 - a step of removing, from among split images obtained by splitting the first image, a split image corresponding to an outer side of the railway vehicle from the center position of the first line sensor camera, and removing, from among split images obtained by splitting the second image, a split image corresponding to the outer side of the railway vehicle from the center position of the second line sensor camera,
- wherein the step of trimming an area outside a target image-capturing range

trims an area outside the target image-capturing range from a first split image remaining without being removed, and trims an area outside the target image-capturing range from a second split image remaining without being removed, and

the step of horizontally inverting

horizontally inverts either the first split image that was trimmed or the second split image that was trimmed such that orientation of the overhead contact line fitting captured in the first split image that was trimmed and orientation of the overhead contact line fitting captured in the second split image that was trimmed match.

6. The overhead contact line fitting abnormality detection method according to claim 4, further comprising:

a step of splitting the first image left and right from the center position of the first line sensor camera in the first image and splitting the second image left and right from the center position of the second line sensor camera in the second image,

wherein the step of trimming an area outside a target image-capturing range trims an area outside the target image-capturing range from a first left split image and a first right split image obtained by splitting the first image left and right, and trims an area outside the target image-capturing range from a second left split image and a second right split image obtained by splitting the second image left and right, and

the step of horizontally inverting

horizontally inverts either the first left split image that was trimmed or the first right split image that was trimmed such that orientations of the overhead contact line fitting in the first left split image and the first right split image that were trimmed match, and horizontally inverts either the second left split image that was trimmed or the second right split image that was trimmed such that orientations of the overhead contact line fitting in the second left split image and the second right split image that were trimmed match.