

DESCRIPTION

TITLE OF INVENTION

LINE ABNORMALITY DETECTION SYSTEM AND LINE ABNORMALITY
DETECTION METHOD

TECHNICAL FIELD

[0001]

The present invention relates to a line abnormality detection system and a line abnormality detection method.

BACKGROUND

[0002]

Conventionally, for electric railway equipment, maintenance and inspection work is performed on overhead electric overhead contact lines (contact wires, messenger wires, auxiliary messenger wires; hereinafter "line"), with maintenance being carried out by inspection personnel visually checking for fraying or breakage, etc., of stranded wires which constitute a line. However, there are limits to visual inspections, and thus, there is a possibility that abnormalities are overlooked.

[0003]

Here, Patent Document 1 discloses technology for detecting a contact wire from a line sensor camera image. Further, Patent Document 2 discloses technology for performing a three-dimensional measurement by combining a line sensor camera image and a range measurement laser to extract an overhead line and a messenger wire.

CITATION LIST

PATENT LITERATURE

[0004]

Patent Document 1: JP 2009-040215 A

Patent Document 2: JP 2015-017882 A

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0005]

However, in Patent Document 1, continuity of an overhead line is evaluated by performing an edge detection process on an image obtained from a line sensor camera but there is a problem in that in image processing, it is not possible to detect a line with certainty.

[0006]

Further, in Patent Document 2, it is necessary to carry out multiple image processing on an image from a line sensor, and therefore, there is a problem in that the processing load for performing three-dimensional measurements increases, and thus, processing takes time.

[0007]

Here, the present invention addresses a problem of providing a line abnormality detection system and a line abnormality detection method which are capable of detecting lines with higher accuracy and in a shorter time.

SOLUTION TO PROBLEM

[0008]

The present invention employs the following means to solve the problem described above.

That is, the line abnormality detection system according to the present invention is a line abnormality detection system for detecting an abnormality in a line including at least a messenger wire and a contact wire for operating a railway vehicle, wherein the line abnormality detection system is characterized by being provided with: an imaging unit that captures an image of the line and fittings accompanying the line; an overhead contact line fitting detection unit that detects the fittings from image data captured by the imaging unit; a line detection unit that detects, from the image data, an image region in which the line is included on the basis of a likelihood indicating an extent to which it is possible to join the fittings to one another in a straight line on the basis of positions of the detected fittings; and a line abnormality detection unit that detects an abnormality in the line from the image region in which the line is included.

[0009]

Further, the line abnormality detection method according to the present invention is a line abnormality detection method for detecting an abnormality in a line including at least a messenger wire and a contact wire for operating a railway vehicle, wherein the line abnormality detection method is characterized by including: capturing, by means of an imaging unit, an image of a line and fittings accompanying the line; detecting the fittings from image data captured by the imaging unit; detecting, from the image data, an image region in which the line is included on the basis of a likelihood indicating an extent to which it is possible to join the fittings to one another in a straight line on the basis of positions of the detected fittings; and detecting an abnormality in the line from the image region in which the

line is included.

EFFECTS OF INVENTION

[0010]

According to the present invention, it is possible to detect a line with more certainty and in a shorter time.

BRIEF DESCRIPTION OF DRAWINGS

[0011]

Fig. 1 is perspective view showing electric railway equipment in which a line abnormality detection system 10 according to a first embodiment of the present invention is used.

Fig. 2 is a block diagram showing the functional configuration of the line abnormality detection system 10 according to the first embodiment.

Fig. 3 is a flowchart for describing the actions of the line abnormality detection system 10 according to the first embodiment.

Fig. 4 is a conceptual diagram for describing a line detection process performed by the line abnormality detection system 10 according to the first embodiment.

Fig. 5 is a conceptual diagram for describing a method for calculating a joining likelihood for a main section performed by the line abnormality detection system 10 according to the first embodiment.

Fig. 6 is a conceptual diagram for describing a method for calculating a joining likelihood for a remaining rectangle performed by the line abnormality detection system 10 according to the first embodiment.

Fig. 7 is a conceptual diagram for describing joining information of a fitting rectangle performed by the line abnormality detection system 10 according to the first embodiment.

Fig. 8 is a conceptual diagram for describing a line rectangle allocation method performed by the line abnormality detection system 10 according to the first embodiment.

Fig. 9 is perspective view showing electric railway equipment in which a line abnormality detection system 10 according to a second embodiment of the present invention is used.

Fig. 10 is a block diagram showing the functional configuration of the line abnormality detection system 10 according to the second embodiment.

Fig. 11 is a flowchart for describing the actions of the line abnormality detection

system 10 according to the second embodiment.

Fig. 12 is schematic diagram showing fitting rectangles in a compound interval in which the line abnormality detection system 10 according to the second embodiment is used.

Fig. 13 is perspective view showing electric railway equipment in which a line abnormality detection system 10 according to a third embodiment of the present invention is used.

Fig. 14 is a block diagram showing the functional configuration of the line abnormality detection system 10 according to the third embodiment.

Fig. 15 is a flowchart for describing the actions of the line abnormality detection system 10 according to the third embodiment.

Fig. 16 is a conceptual diagram for describing a method for calculating a joining likelihood using laser data performed by the line abnormality detection system 10 according to the third embodiment.

DESCRIPTION OF EMBODIMENTS

[0012]

Embodiments for implementing the present invention are explained below with reference to the attached drawings.

The present invention makes it possible to perform line detection automatically in an image acquired from a camera mounted on a roof of a railway vehicle, and the objective of the present invention is to realize labor-saving in line maintenance and inspection work by performing abnormality detection on a line detection image in a latter process.

[0013]

A. First embodiment

Fig. 1 is perspective view showing electric railway equipment in which a line abnormality detection system 10 according to a first embodiment of the present invention is used. In fig. 1, a vehicle 1 is running in a travel direction shown by the arrow. With regard to electric railway equipment, masts 3 are disposed at prescribed intervals along a railway track on which the vehicle 1 runs, and a messenger wire 4 is suspended from the masts 3. In addition, the messenger wire 4 supports a contact wire 5 by hangers 6 (fittings).

[0014]

In the first embodiment, the line abnormality detection system 10 is configured from: two line sensor cameras (imaging units) 11a, 11b which are installed on a vehicle roof 2; and an analysis device 12. The line sensor cameras 11a, 11b are installed so that imaging surfaces thereof face a sleeper direction. That is, the line sensor

cameras 11a, 11b are set so as to capture a line (messenger wire 4, contact wire 5) and the hangers 6 (fittings) from directions diagonally below on the right and left of the vehicle. Note that the reason for using the two line sensor cameras 11a, 11b is in anticipation of an occurrence of a failure, or the like, in which for some reason image capturing not possible. The two line sensor cameras 11a, 11b are for capturing images from each of the left and right directions but the line abnormality detection system 10 according to the present embodiment also can also function with only one line sensor camera.

[0015]

Fig. 1 shows only one line (main line; messenger wire 4 and contact wire 5). However, there are actually cases of there also being lines such as a crossover, etc., which intersect the main line diagonally. In the process below, there are anticipated cases in which, in addition to the lines of the main line, lines such as a crossover, etc., are included and are described as “remaining rectangles”.

[0016]

Fig. 2 is a block diagram showing the functional configuration of the line abnormality detection system 10 according to the first embodiment. As described above, the line abnormality detection system 10 is configured from the line sensor cameras 11a, 11b and an analysis device 12. The analysis device 12 is configured from a storage unit 13, an overhead contact line fitting detection unit 14, a line detection unit 15, and a line abnormality detection unit 16. Image data captured by the line sensor cameras 11a, 11b are saved in the storage unit 13. The line sensor cameras 11a, 11b continuously capture images, and subsequently an analysis process is performed with a section between masts serving as one unit.

[0017]

The overhead contact line fitting detection unit 14 detects fittings (hangers 6) from the image data saved in the storage unit 13 and saves as fitting detection information in the storage unit 13. The line detection unit 15 detects a line (messenger wire 4, contact wire 5) from the fitting detection information saved in the storage unit 13 and saves as line detection information in the storage unit 13. The line abnormality detection unit 16 detects an abnormality in the line (messenger wire 4, contact wire 5) from a line detection information image allocated on the basis of the line detection information saved in the storage unit 13 and saves in the storage unit 13 as an abnormality determination (result).

[0018]

Fig. 3 is a flowchart for describing the actions of the line abnormality detection system 10 according to the first embodiment. First, the overhead contact line fitting detection unit 14 detects an image of a fitting (hanger 6) by performing an overhead contact line fitting detection process on image data 20 between masts saved in the storage unit 13 and acquires fitting detection information 21 in which a fitting detection position (xmin, ymin, xmax, ymax) is associated with a label name (step S10). Note that the method for performing the overhead contact line fitting detection

process is not particularly limited. Said method may, for example, be an object detection model, or the like, using deep learning such as SSD, YOLO, Faster R-CNN, or M2Det.

[0019]

Here, fig. 4 is a conceptual diagram for describing a line detection process performed by the line abnormality detection system 10 according to the first embodiment. As shown in the drawing, for image data, a section between masts serves as one unit. In the case of the image data shown in fig. 4, a case in which two lines (intersecting lines) are captured is shown. The thick lines in the drawing are the hangers 6 (fittings) which suspend the contact wire 5. In the line detection process, all hangers 6 (fittings) in an image are detected, fitting rectangles 6a which surround respective hangers 6 (fittings) are set, and coordinates of the fitting rectangles 6a are acquired as fitting detection positions (x_{min} , y_{min} , x_{max} , y_{max}). Further, in the line detection process, which fitting each hanger 6 (fitting) corresponds to is indicated and a label name is set to differentiate between specific fittings in the image. In that case, label names are “hanger i” ($i=0, 1, \dots, n$).

[0020]

Next, the line detection unit 15 receives the fitting detection information 21 in which the fitting detection positions (x_{min} , y_{min} , x_{max} , y_{max}) of all of the hangers 6 (fittings) included between the masts are associated with respective label names, fitting rectangles 6a determined as being on the same overhead line are joined (process for joining fitting rectangles 6a: steps S14, S16, and S18 below), and finally line detection is performed by allocating line rectangles (process for allocating line rectangles: step S20 below) and line detection information 22 is acquired (step S12).

[0021]

To give a more detailed explanation, from the fitting detection information 21, the line detection unit 15 first registers, for a fitting rectangle 6a, a “hanger” label rectangle as a fitting rectangle to be used in line detection (step S14). Next, the line detection unit 15 joins fitting rectangles of a main section (straight-line section) (step S16). Here, there follows an explanation regarding joining the fitting rectangles of the main section (straight-line section).

[0022]

Fig. 5 is a conceptual diagram for describing a method for calculating a joining likelihood for a main section performed by the line abnormality detection system 10 according to the first embodiment. For joining the main section (straight-line section), a joining likelihood is calculated from positional relationships among each joining candidate. As shown in fig. 5, focusing on fitting rectangle “0” and fitting rectangle “1” as joining candidates, for a joining likelihood, a total likelihood L is calculated by using three parameters, namely, a deviation distance D_x indicating a distance of misalignment in the centroids of the fitting rectangles, a line-direction distance D_y indicating a distance between the fitting rectangles, and an angle θ

indicating an angle of misalignment between the above centroids to obtain, from formulas (1) to (4) below, a deviation distance likelihood L_{Dx} , a line-direction distance likelihood L_{Dy} , and an angle likelihood L_{θ} , weighting each likelihood, and totaling. A main line (running line) appears as a straight line in the image vertical direction, and therefore, the deviation distance D_x and the line-direction distance D_y are considered to be important elements. In addition, rectangles in which the total likelihood L calculated for each is a maximum are joined and registered as a joining origin (parent rectangle) and a joining destination (child rectangle). Accordingly, the total likelihood is larger the smaller is the deviation distance D_x , the closer is the line-direction distance D_y to a prescribed setting interval, and the closer is the angle θ to 0.

[0023]

[MATH 1]

Deviation distance likelihood
$$L_{Dx} = 1 - |D_x|/t_{Dx} \quad (1)$$

Line-direction distance likelihood
$$L_{Dy} = 1 - |D_y - h|/t_{Dy} \quad (2)$$

Angle likelihood
$$L_{\theta} = 1 - |\theta|/t_{\theta} \quad (3)$$

Total likelihood
$$L = w_{Dx}L_{Dx} + w_{Dy}L_{Dy} + w_{\theta}L_{\theta} \quad (4)$$

 (wherein $w_{Dx} + w_{Dy} + w_{\theta} = 1$)

h : Hanger interval

t_{Dx} : Deviation threshold value

t_{Dy} : Line-direction distance likelihood threshold value

t_{θ} : Angle threshold value

w_{Dx} : Deviation likelihood weight

w_{Dy} : Line-direction distance likelihood weight

w_{θ} : Angle likelihood weight

[0024]

Next, the line detection unit 15 joins remaining rectangles other than those of the main section (fitting rectangles other than those of the main section) (step S18). Here, there follows an explanation regarding joining the fitting rectangles of the

remaining rectangles (diagonal section).

[0025]

Fig. 6 is a conceptual diagram for describing a method for calculating a joining likelihood for a remaining rectangle performed by the line abnormality detection system 10 according to the first embodiment. For joining remaining rectangles, among the fitting rectangles that were not joined as a main section, joining likelihoods are calculated from positional relationships of the fitting rectangles which are targets (in fig. 6, the fitting rectangle "1", the fitting rectangle "0" thereabove, and the fitting rectangle "2" therebelow). For the joining likelihood, as shown in fig. 6, a total likelihood L is calculated by using three parameters, namely, a line-direction distance D_{y1} indicating a distance between a first fitting rectangle "0" and a second fitting rectangle "1", a line-direction distance D_{y2} indicating a distance between the second fitting rectangle "1" and a third fitting rectangle "2", and difference angle θ_d indicating an angle formed by a straight line joining the centroids of the first fitting rectangle "0" and the second fitting rectangle "1" and a straight line joining the centroids of the second fitting rectangle "1" and the third fitting rectangle "2" to obtain, from formulas (5) to (8) below, a difference angle likelihood $L_{\theta d}$, a line-direction distance likelihood L_{Dy2} , and a line-direction distance likelihood L_{Dy1} , weighting the likelihoods, and totaling. The remaining rectangles are rectangles in a distribution which is not a straight line in the image vertical direction, and are considered to be a lines in which the crossover, etc., described above is captured diagonally, and therefore, the difference angle θ_d is considered to be an important element. In addition, fitting rectangles in which the total likelihood L is a maximum are registered as a joining origin (parent rectangle) and a joining destination (child rectangle). Accordingly, the smaller is the difference angle θ_d and the closer are the line-direction distance D_{y1} and the line-direction distance D_{y2} to a prescribed setting interval, the larger is the total likelihood.

[0026]

[MATH 2]

$$\text{Difference angle likelihood} \quad L_{\theta d} = 1 - |\theta_d|/t_{\theta d} \quad (5)$$

$$\text{Line-direction distance likelihood}_{(D_{y2})} \quad L_{Dy2} = 1 - |D_{y2} - h|/t_{Dy} \quad (6)$$

$$\text{Line-direction distance likelihood}_{(D_{y1})} \quad L_{Dy1} = 1 - |D_{y1} - h|/t_{Dy} \quad (7)$$

$$\begin{aligned} \text{Total likelihood} \quad L = & w_{\theta d} L_{\theta d} + w_{Dy2} L_{Dy2} \\ & + w_{Dy1} L_{Dy1} \end{aligned} \quad (8)$$

(wherein $w_{\theta d} + w_{Dy2} + w_{Dy1} = 1$)

h : Hanger interval

t_{Dy} : Line-direction distance likelihood threshold value

$t_{\theta d}$: Angular difference threshold value

w_{Dy1} : Line-direction distance likelihood weight (Dy1)

w_{Dy2} : Line-direction distance likelihood weight (Dy2)

$w_{\theta d}$: Angular difference likelihood weight

[0027]

Fig. 7 is a conceptual diagram for describing joining information of a fitting rectangle in the line abnormality detection system 10 according to the first embodiment. As shown in fig. 7, by joining the fitting rectangles of the main section (straight-line section) and joining the remaining rectangles (fitting rectangles) described above, fitting rectangles "0", "2", "4", "6", and "8" are joined as the main section and fitting rectangles "1", "3", "5", "7", and "9" are joined as remaining rectangles. The fittings joined as the main section are denoted joining group G1 and the fittings joined as the remaining rectangles are denoted joining group G2.

[0028]

Next, the line detection unit 15 performs an allocation process to allocate, from the joined fitting rectangles, line rectangles including a line (step S20). In more detail, the line rectangle allocation process is performed for each joining group unit on the basis of fitting rectangle joining information. There follows an explanation regarding allocation of line rectangles for the joining group G1 shown in fig. 7.

[0029]

Fig. 8 (a) and (b) are conceptual diagrams for describing a line rectangle allocation method performed by the line abnormality detection system 10 according to the first embodiment. As shown in fig. 8 (a), areas are divided with a rectangle height position serving as a boundary, and an approximation formula for a line passing through the centroid coordinates of each area is determined. For the uppermost and lowermost areas, a linear function approximation formula is determined from the closest pair of rectangle coordinates. In other cases, a quadratic function approximation formula is determined from three rectangle coordinates including preceding and/or trailing rectangle coordinates.

[0030]

Next, as shown in fig. 8 (b), a line rectangle size is set by using a value of a fitting rectangle having the larger rectangle width among the two fitting rectangles that are closest from the upper edge of the image coordinates, the central coordinates of the line rectangle are set on the line determined by the approximation formula in fig. 8 (a), and line rectangles (square-shaped broken-line rectangles) are allocated in order from the top. The final line rectangle is adjusted by adding a section that does not divide well and is leftover. Further, the next rectangle allocation line position can be adjusted by “rectangle width $\times$ shift ratio (0-1)”.

[0031]

Lastly, as a line abnormality detection process, the line abnormality detection unit 16 uses as an input a line detection image allocated on the basis of the line detection information 22, performs abnormality detection for detecting an abnormality in the line, and ultimately outputs an abnormality determination result (step S22). The abnormality detection method here, is not particularly limited and it is possible, for example, to use image discrimination, etc., using a deep learning object recognition model such as VAE, GAN, ResNET, DeepSAD, CS-FLOW, or the like.

[0032]

According to the first embodiment described above, from the image acquired by the line sensor cameras 11a, 11b mounted on the vehicle roof 2 of the vehicle 1, fittings accompanying a line are detected by the overhead contact line fitting detection unit 14, a line is detected from fitting detection information by the line detection unit 15, and an abnormality in the line is detected from the line detection information and a line image by the line abnormality detection unit 16, and therefore, it is possible to detect a line with higher accuracy and in a shorter time, and it is possible to realize labor-saving in line maintenance and inspection work.

[0033]

Further, according to the first embodiment described above, a likelihood indicating an extent to which fittings can be joined to one another in a straight line is calculated by the line detection unit 15, and a line is detected from image data on the basis of said likelihood. Therefore, it is possible to detect not only a main line but also a line intersecting the main line with higher accuracy and in a shorter time, and it is possible to realize labor-saving in line maintenance and inspection work.

[0034]

B. Second embodiment

Next, a second embodiment of the present invention shall be explained.

Fig. 9 is perspective view showing electric railway equipment in which a line abnormality detection system 10 according to a second embodiment of the present invention is used. The second embodiment relates to a processing on a compound catenary interval. As shown in fig. 9, a compound catenary method is a method in which an auxiliary messenger wire 7 is added between the messenger wire 4 and the contact wire 5, wherein the messenger wire 4 supports the auxiliary messenger wire 7 by droppers 8, and the auxiliary messenger wire 7 supports the contact wire 5 by hangers 6.

[0035]

Fig. 10 is a block diagram showing the functional configuration of the line abnormality detection system 10 according to the second embodiment. Note that sections corresponding to those in the functional configuration of the line abnormality detection system 10 according to the first embodiment shown in fig. 1 have the same reference signs attached thereto and explanations thereof are omitted. In the second embodiment, a fitting identification unit 17 is newly provided. The fitting identification unit 17 acquires fitting detection information in which the hangers 6 and the droppers 8 described above are identified as different fittings. Accordingly, the line detection unit 15 detects, on the basis of the fitting detection information in which individual fittings are identified, a line for each respective fitting rectangle.

[0036]

Fig. 11 is a flowchart for describing the actions of the line abnormality detection system 10 according to the second embodiment. The actions of the line abnormality detection system 10 according to the second embodiment are basically the same as those in the first embodiment. However, an identification process by fitting type performed by the fitting identification unit 17 is added, and the processing by the line detection unit 15 is line detection processing in accordance with fitting type.

[0037]

First, the overhead contact line fitting detection unit 14 detects an image of the fittings (hanger 6, dropper 8) by performing an overhead contact line fitting detection process on image data 20 between masts saved in the storage unit 13 and acquires fitting detection information 21 in which a fitting detection position (xmin, ymin, xmax, ymax) is associated with a label name (step S30). Next, the fitting identification unit 17 acquires, from the fitting detection information 21, fitting detection information 24 in which the hangers 6 and the droppers 8 are identified as different fittings (step S32). The size of the hangers 6 differs from that of the droppers 8, and therefore, the widths of the fitting rectangles are used as information to identify the hangers 6 and the droppers 8.

[0038]

Fig. 12 is schematic diagram showing fitting rectangles in a compound interval in which the line abnormality detection system 10 according to the second embodiment is used. As shown in fig. 12, there is a large difference in rectangle width between the rectangles of the hangers 6 and the fitting rectangles of the droppers 8. Classification methods are not particularly limited and may, for example, involve classifying into two classification groups according to the size of a fitting rectangle width using k-means.

[0039]

Next, the line detection unit 15 receives the fitting detection information 24 in which the fitting detection positions of all of the fittings (hangers 6 and droppers 8) included between masts are associated with a respective label name, fitting rectangles determined as being on the same overhead line are joined, and finally line detection is performed by allocating line rectangles and line detection information 25 is acquired (step S34). Other than the case in which there are different identified fittings (hangers 6, droppers 8), steps S36 to S42 shown in the drawings are the same as steps S14 to S20 in the first embodiment 1, and therefore, explanations thereof are omitted. In the fitting rectangle joining process, it is possible to raise line detection accuracy in a compound catenary interval by deeming only rectangles having the same label as one another (same fittings) as being rectangles which are candidates for joining. Accordingly, in the second embodiment, line rectangles which could be obtained by joining hangers 6 to one another, and line rectangles which could be obtained by joining droppers 8 to one another are acquired as the line detection information 25.

[0040]

Lastly, as a line abnormality detection process, the line abnormality detection unit 16 uses as an input a line detection image allocated on the basis of the line detection information 25, which includes line rectangles which could be obtained by joining hangers 6 to one another, and line rectangles which could be obtained by joining droppers 8 to one another, performs abnormality detection for detecting an abnormality in the line, and ultimately outputs an abnormality determination result 26 (step S44). In the same manner as in the first embodiment, the abnormality detection method here is not particularly limited and it is possible, for example, to use image discrimination, etc., using a deep learning object recognition model.

[0041]

Note that the second embodiment described above has the fitting identification unit 17 provided but without being limited thereto, in the overhead contact line fitting detection unit 14, hangers 6 and droppers 8 are each detected as fittings and labeled ("hanger", "dropper"), and in the line detection unit 15, hangers 6 and droppers 8 are registered in accordance with the respective label. Thus, the overhead contact line fitting detection unit 14 and the line detection unit 15 may also be configured to share the function of the fitting identification unit 17.

[0042]

According to the second embodiment described above, in a compound catenary interval, from the image acquired by the line sensor cameras 11a, 11b mounted on the vehicle roof 2 of the vehicle 1, fittings accompanying a line are detected, different fittings are classified, a line is detected from fitting detection information for each classified fitting, and an abnormality in the line is detected from the line detection information and a line image, and therefore, it is possible to detect a messenger wire, an auxiliary messenger wire, and a contact wire used in a compound catenary interval with higher accuracy and in a shorter time, and it is possible to realize labor-saving in line maintenance and inspection work.

[0043]

Further, according to the first embodiment described above, a likelihood indicating an extent to which fittings can be joined to one another in a straight line is calculated, and a line is detected from image data on the basis of said likelihood. Therefore, it is possible to detect, not only for a main line but also for a line intersecting the main line, a messenger wire, an auxiliary messenger wire, and a contact wire used in a compound catenary interval with higher accuracy and in a shorter time, and it is possible to realize labor-saving in line maintenance and inspection work.

[0044]

C. Third Embodiment

Next, a third embodiment of the present invention shall be explained.

Fig. 13 is perspective view showing electric railway equipment in which a line abnormality detection system 10 according to a third embodiment of the present invention is used. Note that sections corresponding to those in fig. 1 have the same reference signs attached thereto and explanations thereof are omitted. In the second embodiment, in addition to the line sensor cameras 11a, 11b, a range measurement laser 18 is added and disposed on the vehicle roof 2. The range measurement laser 18 acquires, as laser data: a distance to a line (messenger wire 4 and contact wire 5) and a fitting (hanger 6); and an elevation angle with respect to the line (messenger wire 4 and contact wire 5) and the fitting (hanger 6).

[0045]

Fig. 14 is a block diagram showing the functional configuration of the line abnormality detection system 10 according to the third embodiment. Note that sections corresponding to those in fig. 2 have the same reference signs attached thereto and explanations thereof are omitted. The range measurement laser 18 acquires and saves, as laser data in the storage unit 13: the distance to the line (messenger wire 4 and contact wire 5); and the elevation angle with respect to the line (messenger wire 4 and contact wire 5). Accordingly, the line detection unit 15 detects a line for each fitting rectangle on the basis of the fitting detection information classified for each fitting and the laser data.

[0046]

Fig. 15 is a flowchart for describing the actions of the line abnormality detection system 10 according to the third embodiment. The actions of the line abnormality detection system 10 according to the third embodiment are basically the same as those in the first embodiment. However, the processing by the line detection unit 15 is line detection processing using the fitting detection information and the laser data.

[0047]

First, the overhead contact line fitting detection unit 14 detects an image of the fittings (hangers 6) by performing an overhead contact line fitting detection process on image data 20 between masts saved in the storage unit 13 and acquires fitting detection information 21 in which a fitting detection positions are associated with a respective label name (step S50).

[0048]

Next, the line detection unit 15 receives the fitting detection information 21 in which the fitting detection positions of all of the fittings (hangers 6) included between masts are associated with a respective label name, and laser data 30 acquired by the range measurement laser 18, fitting rectangles determined as being on the same overhead line are joined, and finally line detection is performed by allocating line rectangles and line detection information 25 is acquired (step S52).

[0049]

In the third embodiment, the steps S54 to S60 shown in the drawings are the same as the steps S14 to S20 in the first embodiment. However, an explanation is provided regarding a method for calculating a likelihood using the laser data 30 which differs from the first embodiment.

[0050]

Fig. 16 (a) to (d) are conceptual diagrams for describing a method for calculating a joining likelihood using the laser data 30 performed by the line abnormality detection system 10 according to the third embodiment. A likelihood term using the laser data 30 is added in joining the main section in step S56. As shown in fig. 16 (a) to (d), a likelihood using the laser data 30 is calculated by the flow described below. First, as shown in fig. 16 (a), the presence of laser points is confirmed in the fitting rectangle "0" which serves as a joining origin (if not present, the likelihood is 0), and as shown in fig. 16 (b), a linear approximation formula for a line between the fitting rectangle "0" and a fitting rectangle "1" which is a candidate for joining is calculated. Next, as shown in fig. 16 (c), a laser angle θ_l based on the linear approximation formula, and a rectangle angle θ based on a straight line joining the centroids of the fitting rectangles "1" and "2" are calculated, and as shown in fig. 16 (d), a difference angle θ_{sl} , which is a difference between the laser angle θ_l and the rectangle angle θ is calculated. In addition, from formula (9) below, there is calculated a laser likelihood L_l indicating an extent of misalignment between a straight line joining the centroids of the fitting rectangles and a straight line made by the laser expressed by a linear

approximation formula.

[0051]

[MATH 3]

$$\text{Laser likelihood} \quad L_l = 1 - |\theta_{sl}| / t_{\theta sl} \quad (9)$$

$$\begin{aligned} \text{Total likelihood} \quad L &= w_{Dx} L_{Dx} + w_{Dy} L_{Dy} + w_{\theta} L_{\theta} \\ &\quad + w_l L_l \end{aligned} \quad (10)$$

(wherein $w_{Dx} + w_{Dy} + w_{\theta} + w_l = 1$)

L_l	Laser likelihood
θ_{sl}	Difference angle between laser angle θ_l and rectangle angle θ
$t_{\theta sl}$	Threshold value for difference angle between laser angle θ_l and rectangle angle θ
w_l	Laser likelihood weight

[0052]

For the laser likelihood L_l , a calculation for all channels of inputted laser data 30 is performed, and the highest total likelihood L is used (the laser tracks the same overhead line and is managed in channels). A total value obtained by weighting and totaling the laser likelihood L_l , and the deviation distance likelihood L_{dx} , the line-direction distance likelihood L_{dy} , and the angle likelihood L_{θ} of the first embodiment is a total likelihood L that a candidate rectangle is joined (formula (10)). Since there is more input information than in the case of the first embodiment, it is possible to perform line detection more accurately. With respect to joining the remaining rectangles in step S58, too, line detection is performed in the same manner by using the laser data 30. Further, regarding line rectangle allocation in step S60, the same processing as in the first and second embodiments is performed.

[0053]

Lastly, as a line abnormality detection process, the line abnormality detection unit 16 uses as an input a line detection image allocated on the basis of the line detection information 31, performs abnormality detection for detecting an abnormality in the line, and ultimately outputs an abnormality determination result 32 (step S64). In the same manner as in the first and second embodiments described above, the abnormality detection method here is not particularly limited and it is possible, for example, to use image discrimination, etc., using a deep learning object recognition model.

[0054]

According to the third embodiment described above, fittings accompanying a line are detected from the image acquired by the line sensor cameras 11a, 11b mounted on the vehicle roof 2 of the vehicle 1, and from fitting detection information and the laser data 30 acquired by the range measurement laser 18, a likelihood indicating an extent to which the fittings can be joined to one another in a straight line is calculated, a line is detected from the image data on the basis of said likelihood, and an abnormality in the line is detected from the line detection information and the line image, and therefore, it is possible to detect a line with higher accuracy and in a shorter time, and it is possible to realize labor-saving in line maintenance and inspection work.

REFERENCE SIGNS LIST

[0055]

1	Vehicle
2	Vehicle roof
3	Mast
4	Messenger wire
5	Contact wire
6	Hanger
7	Auxiliary messenger wire
8	Dropper
10	Line abnormality detection system
11a, 11b	Line sensor camera
12	Analysis device
13	Storage unit
14	Overhead contact line fitting detection unit
15	Line detection unit
16	Line abnormality detection unit
17	Fitting identification unit
18	Range measurement laser
20	Image data
21	Fitting detection information
22, 25, 31	Line detection information
23, 26, 32	Abnormality determination result
24	Fitting detection information (identified)
30	Laser data

CLAIMS

[Claim 1]

A line abnormality detection system for detecting an abnormality in a line including at least a messenger wire and a contact wire for operating a railway vehicle, wherein the line abnormality detection system is characterized by being provided with:

- an imaging unit that captures an image of the line and fittings accompanying the line;

- an overhead contact line fitting detection unit that detects the fittings from image data captured by the imaging unit;

- a line detection unit that detects, from the image data, an image region in which the line is included on the basis of a likelihood indicating an extent to which it is possible to join the fittings to one another in a straight line on the basis of positions of the detected fittings; and

- a line abnormality detection unit that detects an abnormality in the line from the image region in which the line is included.

[Claim 2]

The line abnormality detection system according to claim 1, characterized in that:

- the line comprises, in addition to the messenger wire and the contact wire, an auxiliary messenger wire, and the fittings comprise at least hangers that support the contact wire, and droppers that support the auxiliary messenger wire;

- the line abnormality detection system further comprises a fitting identification unit which identifies the hangers and the droppers from the image data; and

- the line detection unit distinguishes between the hangers and the droppers and detects, from the data image, an image region in which the line is included.

[Claim 3]

The line abnormality detection system according to claim 1 or 2, characterized in

- that the line detection unit detects, from the image data, an image region in which the line is included on the basis of a total likelihood comprising: a deviation distance likelihood indicating a misalignment in the centroids of at least two fittings included in the image data; a line-direction distance likelihood corresponding to a distance between the two fittings; and an angle likelihood corresponding to an angle of misalignment in the centroids of the two fittings.

[Claim 4]

The line abnormality detection system according to claim 1, characterized in that

the line detection unit detects, from the image data, an image region in which the line is included on the basis of a total likelihood obtained by totaling: a line-direction distance likelihood corresponding to a distance between a first fitting and a second fitting among at least three fittings included in the image data; a line-direction distance likelihood corresponding to a distance between the second fitting and a third fitting; and a difference angle likelihood corresponding to an angle formed by a straight line joining the centroids of the first fitting and the second fitting, and a straight line joining the centroids of the second fitting and the third fitting.

[Claim 5]

The line abnormality detection system according to claim 1, characterized by

further comprising a range measurement laser for acquiring a distance and an elevation angle to the line and the fittings,

wherein the line detection unit detects, from the image data, an image region in which the line is included on the basis of a likelihood indicating an extent to which the fittings can be joined to one another in a straight line on the basis of positions of the detected fittings and the distance and the elevation angle acquired by the range measurement laser.

[Claim 6]

The line abnormality detection system according to claim 5, characterized in that

the line detection unit detects, from the image data, an image region in which the line is included on the basis of a total likelihood obtained by totaling: a laser likelihood corresponding an extent of misalignment between an angle formed by a straight line joining the centroids of at least two fittings included in the image data and an angle formed by laser points made by the range measurement laser: a deviation distance likelihood indicating a misalignment in the centroids of the at least two fittings; a line-direction distance likelihood corresponding to a distance between the at least two fittings; and an angle likelihood corresponding to an angle of misalignment in the centroids of the at least two fittings.

[Claim 7]

A line abnormality detection method for detecting an abnormality in a line including at least a messenger wire and a contact wire for operating a railway vehicle, wherein the line abnormality detection method is characterized by comprising:

capturing, by means of an imaging unit, an image of the line and fittings accompanying the line;

detecting the fittings from image data captured by the imaging unit;

detecting, from the image data, an image region in which the line is included on the basis of a likelihood indicating an extent to which it is possible to join the fittings to one another in a straight line on the basis of positions of the detected fittings; and

detecting an abnormality in the line from the image region in which the line is included.