

DESCRIPTION

TITLE OF THE INVENTION: WIRE MEASUREMENT DEVICE AND METHOD
TECHNICAL FIELD

[0001]

The present invention pertains to the field of managing contact wires in railways and particularly relates to wire measurement device and method which perform image processing on data obtained by line cameras installed on a rooftop of a train and which measure the height and deviation of a contact wire out of wires.

BACKGROUND ART

[0002]

The techniques disclosed in Patent Documents 1 and 2 listed below can be given as examples of techniques for measuring the height and deviation of wires including a contact wire.

[0003]

Patent Document 1 listed below discloses a technique in which a line camera is installed on a rooftop of a train and sensor data of the line camera is obtained while the train is traveling to measure the wear and deviation of the contact wire.

[0004]

Patent Document 2 listed below discloses a technique in which line cameras and a laser range finder are installed on a rooftop of a train and sensor data of the line cameras and the laser range finder is obtained while the train is traveling to measure the height and deviation of the contact wire.

[0005]

Management of position information of the contact wire (contact wire position measurement) needs to be performed in

a range of deviation of ± 900 mm from the center of the railroad car. The reason for this is as follows.

[0006]

Generally, the contact wire is at a position within a range of ± 250 mm (± 300 mm in the case of Shinkansen) from the "center" of a pantograph in the left-right direction, so that the train can collect electric power through the pantograph. However, in areas near an air section installation around an overlap and a crossover installation in which two tracks intersect, an "end" of the pantograph may come into contact with a second contact wire (contact wire other than a main wire). The contact wire position measurement thus needs to be performed in the range of deviation of ± 900 mm from the center of the railroad car.

[0007]

Note that the aforementioned "deviation," "wires," "overlap," "air section," "crossover," and "sliding surface" are defined as follows.

[0008]

The "deviation" refers to the distance from the center of the pantograph to the position of the wire in the horizontal direction.

[0009]

The "wires" refer to wires suspended in midair and include wires such as the contact wire, a messenger wire, and a feeder cable.

[0010]

The "overlap" is an installation in which the contact wires are electrically or mechanically separated, and refers to an air section or an air joint.

[0011]

The "air section" is a portion in which front and rear contact wires (wires on the front side and rear side in the railroad car traveling direction) are not electrically connected but separated in the overlap. Fig. 17 is a top view explaining the air section. Fig. 17 illustrates a state where a main wire 1 and a secondary main wire 2 overlap each other without being electrically connected but separated, above a track 3. Moreover, the "air joint" is a portion in which the wires are electrically connected in the air section.

[0012]

The "crossover" is an installation in which two sets of contact wires above a railroad switch intersect each other such that no disruption occurs when the pantograph passes the crossover. Fig. 18 is a top view explaining the crossover. Fig. 18 illustrates a state where a crossover wire 4 intersects the main wire 1 above a track 3 in which a railroad switch 3a is disposed.

[0013]

The "sliding surface" refers to a surface of the contact wire which is worn by coming into contact with the pantograph. Generally, since the contact wire is always in contact with the pantograph, the sliding surface exists in the contact wire. However, in an installation section where there is a second contact wire such as the air section and the crossover, there is a portion which does not come into contact with the pantograph, that is a portion without the sliding surface in the range of deviation of ± 900 mm from the railroad car center in which the management is necessary.

[0014]

Moreover, the "management of the contact wire" refers to

regularly checking whether the height, deviation, and wear of the contact wire are equal to or lower than predetermined management values. Accidents can be prevented by managing the contact wire.

[0015]

The "height of the contact wire" refers to the height from the track to the contact wire installed above the train and is generally about 4500 mm (5000 mm in the case of Shinkansen).

[0016]

The "deviation of the contact wire" refers to the position of the contact wire in the horizontal direction. Generally, the contact wire is at a position within a range of ± 250 mm (± 300 mm in the case of Shinkansen) from the pantograph center in the left-right direction. In the air section and crossover installation portions, the management is performed also at positions deviated from the vehicle center within the range of ± 900 mm at which the second wire exists, in addition to the aforementioned position.

[0017]

The "wear of the contact wire" refers to wear of the contact wire occurring in proportion to the frequency of passing of the train (pantograph). The management is performed such that the wear does not exceed a wear limit value.

PRIOR ART DOCUMENT

PATENT DOCUMENT

[0018]

Patent Document 1: Japanese Patent Application Publication No. 2010-127746

Patent Document 2: Japanese Patent Application Publication No. 2012-8026

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0019]

As paragraph [0035] of the aforementioned Patent Document 1 states that "contact wire height data is inputted from the outside," the technique of Patent Document 1 additionally requires height information and cannot measure the position (height and deviation) of the contact wire by itself. Moreover, only the worn contact wire is the target of the measurement and the wires in the air section and the crossover cannot be measured.

[0020]

The aforementioned Patent Document 2 requires installing two line cameras and one laser range finder on the rooftop of the train. Accordingly, the configuration of the device installed on the rooftop is complex and large. Moreover, the position information of the laser range finder is used for point matching in the stereo measurement. Since the laser has such a characteristic that the detection rate and accuracy decrease in proportion to the measurement distance, the stereo measurement of distant contact wires in the crossover, the air section, and the like is difficult to perform. Moreover, the data obtaining cycle with the laser is 10 times or more slower than that of the line cameras and it is difficult to mount the wire measurement device using the laser on a high-speed railroad car such as a commercial railroad car.

[0021]

The present invention has been made in view of the technical situation described above and an object thereof is to provide wire measurement device and method which can measure

the height and deviation in a wide range by using only line cameras and which can also measure, as measurement targets, not only a main wire but also a second contact wire (contact wire other than the main wire) whose deviation from a railroad car center is within a range of ± 900 mm.

MEANS FOR SOLVING THE PROBLEMS

[0022]

A wire measurement device in a first aspect of the present invention for solving the problems described above includes: a first line camera and a second line camera which are disposed at both ends of a rooftop of a railroad car in a railroad-tie direction to be tilted toward a center of the railroad car in the railroad-tie direction and which captures images of wires; and an image processing unit which calculates height and deviation of a measurement target wire by detecting wire information and sliding surface information of the measurement target wire from the image captured by the first line camera and the image captured by the second line camera, and by performing matching for the measurement target wire between the captured images by using the wire information and the sliding surface information.

[0023]

A wire measurement device in a second aspect of the present invention for solving the problems described above is the wire measurement device in the first aspect in which when the sliding surface information do not exist in the measurement target wire, the image processing unit performs the matching by using information on time at which the measurement target wire intersects a contact wire having a sliding surface and the sliding surface information of the contact wire.

[0024]

A wire measurement device in a third aspect of the present invention for solving the problems described above is the wire measurement device in the second aspect in which the image processing unit includes: a sliding surface extracting unit which detects the sliding surface information from the image captured by the first line camera and the image captured by the second line camera; a wire extracting unit which detects the wire information from each of the image captured by the first line camera and the image captured by the second line camera; a joining unit which creates joined wire information from the wire information; a matching unit which performs the matching by using the sliding surface information when the sliding surface information exists in the measurement target wire and which performs the matching by using the information on time at which the measurement target wire intersects the contact wire having the sliding surface and the sliding surface information of the contact wire when the sliding surface information does not exist in the measurement target wire; and a stereo measuring unit which calculates the height and deviation of the measurement target wire by performing stereo measurement of matched pieces of joined wire information out of pieces of the joined wire information in the image captured by the first line camera and the image captured by the second line camera.

[0025]

A wire measurement method in a fourth aspect of the present invention for solving the problems described above includes: disposing a first line camera and a second line camera which captures images of wires at both ends of a rooftop of a railroad car in a railroad-tie direction such that the first line camera

and the second line camera are tilted toward a center of the railroad car in the railroad-tie direction: and calculating height and deviation of a measurement target wire by detecting wire information and sliding surface information of the measurement target wire from the image captured by the first line camera and the image captured by the second line camera, and by performing matching for the measurement target wire between the captured images by using the wire information and the sliding surface information.

[0026]

A wire measurement method in a fifth aspect of the present invention for solving the problems described above is the wire measurement method in the fourth aspect in which includes: when the sliding surface information do not exist in the measurement target wire, performing the matching by using information on time at which the measurement target wire intersects a contact wire having the sliding surface and the sliding surface information of the contact wire.

[0027]

A wire measurement method in a sixth aspect of the present invention for solving the problems described above is the wire measurement method in the fifth aspect in which includes: detecting the sliding surface information from the image captured by the first line camera and the image captured by the second line camera, detecting the wire information from the image captured by the first line camera and the image captured by the second line camera, creating joined wire information from the wire information, performing the matching by using the sliding surface information when the sliding surface information exists in the measurement target wire and

performing the matching by using the information on time at which the measurement target wire intersects the contact wire having the sliding surface and the sliding surface information of the contact wire when the sliding surface information does not exist in the measurement target wire, calculating the height and deviation of the measurement target wire by performing stereo measurement of matched pieces of joined wire information out of pieces of the joined wire information in the image captured by the first line camera and the image captured by the second line camera.

EFFECT OF THE INVENTION

[0028]

The wire measurement device and method according to the present invention can measure the height and deviation within a wide range by using only the line cameras, and can also measure, as measurement targets, not only a main wire but also a second contact wire (contact wire other than the main wire) whose deviation from a railroad car center is within a range of ± 900 mm.

[0029]

Moreover, since the wire measurement device and method according to the present invention performs the stereo measurement by using only the line cameras, the detection rate and accuracy in the stereo measurement of the distant contact wires in the crossover, the air section, and the like are less likely to decrease.

[0030]

Furthermore, since the wire measurement device and method according to the present invention performs the stereo measurement by using only the line cameras, the wire measurement

device can be mounted on a high-speed railroad car such as a commercial railroad car.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031]

[Fig. 1] Fig. 1 is a schematic diagram explaining a device configuration of a wire measurement device according to an embodiment of the present invention.

[Fig. 2] Fig. 2 is a schematic diagram explaining a measurement target area and imaging areas of the wire measurement device according to the embodiment of the present invention.

[Fig. 3] Fig. 3 is a schematic diagram explaining the measurement target area and the imaging areas in the case where the line cameras are installed in the vertical direction.

[Fig. 4] Fig. 4 is a diagram comparing the imaging range angle of view in the case where a first line camera is installed in the vertical direction and that in the case where the first line camera is obliquely installed.

[Fig. 5] Fig. 5 is a diagram comparing the imaging range angle of view in the case where a second line camera is installed in the vertical direction and that in the case where the second line camera is obliquely installed.

[Fig. 6] Fig. 6 illustrates example views of captured images of an air section installation.

[Fig. 7] Fig. 7 illustrates data diagram examples of detection results of a sliding surface in the air section installation.

[Fig. 8] Fig. 8 illustrates data diagram examples of detection results of wires in the air section installation.

[Fig. 9] Fig. 9 is a schematic diagram explaining a

functional configuration of the wire measurement device according to the embodiment of the present invention.

[Fig. 10] Fig. 10 includes diagrams illustrating matching results for a main wire 1 and a secondary main wire 2 in the air section installation.

[Fig. 11] Fig. 11 is a schematic view illustrating a state where a railroad car passes a crossover installation.

[Fig. 12] Fig. 12 illustrates example views of captured images of the crossover installation.

[Fig. 13] Fig. 13 includes data diagrams illustrating matching results of the main wire and the crossover wire in the crossover installation.

[Fig. 14] Fig. 14 is a graph illustrating an example of the contact wire measurement results.

[Fig. 15] Fig. 15 is a flowchart explaining operations of an image processing unit in the embodiment of the present invention.

[Fig. 16] Fig. 16 is a flowchart explaining operations of the matching unit in the embodiment of the present invention in detail.

[Fig. 17] Fig. 17 is a top view explaining the air section.

[Fig. 18] Fig. 18 is a top view explaining the crossover.

[Fig. 19] Fig. 19 is a schematic view explaining imaging areas of line cameras.

[Fig. 20] Fig. 20 is a schematic view explaining a stereo imaging performable area using a first line camera and a third line camera.

[Fig. 21] Fig. 21 is a schematic view explaining a stereo imaging performable area using a second line camera and the third line camera.

MODE FOR CARRYING OUT THE INVENTION

[0032]

In wire measurement device and method according to the present invention, two line cameras are installed on a rooftop of a train and data obtained by the line cameras are subjected to image processing. The wire measurement device and method can thereby measure the height and deviation of a contact wire out of wires whose deviation from the railroad car center is within ± 900 mm.

[0033]

The wire measurement device and method according to the present invention are described below in an embodiment by using the drawings.

EMBODIMENT

[0034]

Japanese Patent Application No. 2014-196032 discloses a technique in which a total of three line cameras are installed, specifically one camera is installed at each of both ends of a rooftop of a train in a railroad-tie direction and one camera is installed at the center of a railroad car to measure the position and wear of a contact wire. This technique is a technique in which sensor data is obtained by using the line cameras installed on the rooftop of the train while the train is traveling, and the position and wear of the contact wire are measured.

[0035]

In addition to the technique disclosed in the aforementioned Patent Document 2, this technique can secure imaging areas including a management range (example: deviation of ± 900 mm from the railroad car center) of a second contact

wire such as a crossover wire, by using a three-line camera configuration in which a camera with a wide angle lens is placed at the center. The imaging area is illustrated in Figs. 19 to 21.

[0036]

Fig. 19 is a schematic view explaining imaging areas of the respective line cameras. As illustrated in Fig. 19, the imaging area of a first line camera 31 disposed at one end of a rooftop 30a of the railroad car in the railroad-tie direction and the imaging area of a third line camera 33 disposed at the center of the rooftop 30a overlap each other, and the imaging area of a second line camera 32 disposed at the other end of the rooftop 30a in the railroad-tie direction and the imaging area of the third line camera 33 overlap each other (areas illustrated by the broken lines in Fig. 19 are the imaging areas of the first and second line cameras 31, 32 and an area illustrated by the solid lines is the imaging area of the third line camera 33). Since stereo imaging can be performed in these overlapping areas, these areas are referred to as "stereo imaging performable areas."

[0037]

Fig. 20 is a schematic view explaining the stereo imaging performable area using the first line camera 31 and the third line camera 33. Fig. 21 is a schematic view explaining the stereo imaging performable area using the second line camera 32 and the third line camera 33.

[0038]

As illustrated by a gray zone in Fig. 20, the imaging area of 900 mm on one side is secured by a pattern of the first line camera 31 and the third line camera 33 and, as illustrated by

a gray zone in Fig. 21, the imaging area of 900 mm on the other side is secured by a pattern of the second line camera 32 and the third line camera 33.

[0039]

Moreover, since main wire position information of the contact wire is obtained to impose a limit on height information of the crossover wire, it is possible to limit matching points used in stereo measurement and perform wire measurement of the crossover wire.

[0040]

However, the stereo imaging using the third line camera 33 and the first line camera 31 or the second line camera 32 has a problem that, since the distance between the line cameras is small, the stereo resolution is low.

[0041]

Moreover, since the line camera to be used is switched over between the first line camera 31 and the second line camera 32 depending on the imaging area handled by the respective cameras, processing is complex.

[0042]

Furthermore, this stereo imaging has the following problem. Although the crossover wire is measured by imposing a limit on the information on the height from the main wire, this method can be used only for the crossover wire (condition: "the crossover wire is installed at a height of 30 mm or lower from the main wire"). The position measurement is difficult to perform by using the method of imposing a limit on the height, for an installation with a complex structure and for a target such as an air section whose portion deviating from the railroad car center by ± 900 mm is at a high position.

[0043]

A device configuration of the wire measurement device according to the embodiment is illustrated in Fig. 1. Fig. 1 illustrates a state where a railroad car 10 traveling on a track 3 passes an air section installation portion of a main wire 1 and a secondary main wire 2 which are suspended from messenger wires 1a, 2a. Note that, the messenger wires 1a, 2a are supported by pull-off arms 7 attached to electric poles 6. A feeder cable 5 is attached to the electric poles 6 in addition to the pull-off arms 7.

[0044]

As illustrated in Fig. 1, the wire measurement device according to the embodiment includes: a first line camera 11 and a second line camera 12 which are installed at both ends of a rooftop 10a of the railroad car 10 in the railroad-tie direction and disposed to be tilted toward the center of the railroad car 10 in the railroad-tie direction and which captures images of wires; and an image processing unit 9 to be described later.

[0045]

A stereo imaging area of a wide range (example: deviation of ± 900 mm from the railroad car center) can be thereby secured for the air section (and crossover) and the like. Note that, in the wire measurement device according to the embodiment, a lighting 13 for illuminating the wires may be provided between the first line camera 11 and the second line camera 12 as illustrated in Fig. 1.

[0046]

Fig. 2 illustrates an area in which the stereo measurement can be performed when the first line camera 11 and the second

line camera 12 are tilted toward the center of the railroad car 10 in the railroad-tie direction as in the wire measurement device according to the embodiment, and Fig 3 illustrates an area in which the stereo measurement can be performed when the first line camera 11 and the second line camera 12 are not tilted and directed in the vertical direction.

[0047]

As illustrated in Fig. 3, generally, when the first and second line cameras 11, 12 are installed to be directed in the vertical direction in a limited installing environment on the rooftop 10a of the railroad car 10, since a wide-range stereo imaging area is required in installations such as the air section and the crossover as described above ("measurement target area" in the drawing), stereo imaging impossible areas a, b in which the imaging areas of the cameras do not overlap are formed in the measurement target area (area illustrated by two-dot chain lines, the same applies to Figs. 2, 4, and 5) and the stereo measurement cannot be performed in these areas.

[0048]

Meanwhile, in the wire measurement device according to the embodiment, as illustrated in Fig. 2, an area in which the imaging areas of the cameras do not overlap, that is an area in which the stereo measurement cannot be performed is not formed.

[0049]

This point is described in detail by using Figs. 4 and 5. Fig. 4 is a diagram comparing the imaging range angle of view of the first line camera 11 in the case where the first line camera 11 is installed in the vertical direction and that in the case where the first line camera 11 is obliquely installed.

Fig. 5 is a diagram comparing the imaging range angle of view of the second line camera 12 in the case where the second line camera 12 is installed in the vertical direction and that in the case where the second line camera 12 is obliquely installed. Note that the broken lines in Figs. 4 and 5 illustrate the imaging range in the case where the line cameras are installed in the vertical direction and the solid lines illustrate the imaging range in the case where the line cameras are obliquely installed.

[0050]

The first line camera 11 is tilted so as to be capable of performing the stereo imaging in the stereo imaging impossible area b as illustrated in Fig. 4, and the second line camera 12 is tilted so as to be capable of performing the stereo imaging in the stereo imaging impossible area a as illustrated in Fig. 5. As illustrated in Fig. 2, a measurement target area of a wide range (for the crossover, the air section (deviation of ± 900 mm), and the like) can be thereby secured.

[0051]

Moreover, the image processing unit 9 obtains (detects) wire information and sliding surface information to perform appropriate matching for multiple wires in the images captured by the first line camera 11 and the second line camera 12 in the stereo measurement, and performs the matching for the wires between the images captured by the first line camera 11 and the second line camera 12 by using the detected wire information and sliding surface information. External devices such as a laser device and a height measurement device which are conventionally required are thus unnecessary and the position (height and deviation) of the contact wire whose deviation is

in the range of ± 900 mm in the air section, the crossover, or the like can be measured (calculated) by using only the wire measurement device.

[0052]

A major problem in the contact wire position measurement is the matching of pieces of wire data (wire information) between the line cameras. For example, Fig. 6 illustrates images obtained when the contact wire information in the air section installation of Fig. 1 is captured by the first line camera 11 and the second line camera 12. The view illustrated in part A of Fig. 6 is a view of the image captured by the first line camera 11 and the view illustrated in part B of Fig. 6 is a view of the image captured by the second line camera 12. The horizontal axis of each view represents the pixel (pix) of the camera and the vertical axis of each view represents time (ms).

[0053]

Matching for the wires (the main wire 1, the secondary main wire 2, and the like in the drawings) in the two captured images illustrated in parts A and B of Fig. 6 is difficult to perform by visual determination (as information for this matching, laser information is utilized in the aforementioned Patent Document 2 and the height information of the main wire is utilized in the aforementioned Japanese Patent Application No. 2014-196032).

[0054]

The image processing unit 9 utilizes sliding surface data (sliding surface information) for this matching. Fig. 7 illustrates data diagram examples of detection results of sliding surface in the air section installation. The diagram illustrated part A of Fig. 7 is a diagram based on the image

captured by the first line camera 11 and the diagram illustrated part B of Fig. 7 is a diagram based on the image captured by the second line camera 12. Fig. 8 illustrates data diagram examples of detection results of the wires in the air section installation. The diagram illustrated part A of Fig. 8 is a diagram based on the image captured by the first line camera 11 and the diagram illustrated part B of Fig. 8 is a diagram based on the image captured by the second line camera 12.

[0055]

Specifically, the image processing unit 9 detects the data of the sliding surface 8 from the captured images illustrated in parts (a) and (b) of Fig. 6 as illustrated in Fig. 7. Moreover, the image processing unit 9 detects the wire data from the captured images illustrated in parts (a) and (b) of Fig. 6 as illustrated in Fig. 8 and performs the matching based on information that "the wire data having the sliding surface in the image captured by the first line camera and the image captured by the second line camera 12 is a measurement target." Matching can be thereby performed for any contact wire which at least partially has the sliding surface.

[0056]

Fig. 9 is a functional configuration diagram of the wire measurement device according to the embodiment. As illustrated in Fig. 9, the wire measurement device according to the embodiment includes the first line camera 11, the second line camera 12, and the image processing unit 9. Moreover, the image processing unit 9 includes an image inputting unit 14, a sliding surface extracting unit 15, a wire extracting unit 16, a joining unit 17, a matching unit 18, a stereo measuring unit 19, a storage unit 20, and an installation data setting unit 21.

[0057]

The image inputting unit 14 obtains the image data captured by the first line camera 11 and the second line camera 12.

[0058]

The sliding surface extracting unit 15 detects the sliding surface data from Fig. 6 as illustrated in Fig. 7 as described above, by performing image processing.

[0059]

The wire extracting unit 16 detects the wire data from Fig. 6 as illustrated in Fig. 8 as described above, by performing the image processing. In this case, the wire data is a collection of point clouds and there is no correlation among the pieces of data. Accordingly, the wire data is hereafter referred to as "wire point cloud data (wire point cloud information)." Moreover, in Fig. 8, portions where disturbance such as the electric poles 6 exist are missing portions.

[0060]

The joining unit 17 creates a "joined wire data" in which the pieces of wire point cloud data are joined in the following procedure to form a wire.

[0061]

Specifically, the joining unit 17 first joins continuous pieces of wire point cloud data to create parts. In this case, an overlapping portion and a missing portion are distinguished as other parts. Next, the joining unit 17 joins the parts by utilizing information such as the length, the angle, the coefficient of an approximate quadratic curve, and the starting and ending coordinates of each part to form the joined wire data (joined wire information) from the separate pieces of wire point

cloud data.

[0062]

The matching unit 18 first sets the joined wire data including the sliding surface data as the measurement target wire and matches pieces of the joined wire data in the image captured by the first line camera 11 and the image captured by the second line camera 12.

[0063]

Fig. 10 includes diagrams illustrating matching results for the main wire 1 and the secondary main wire 2 in the air section installation. The diagram illustrated in part A of Fig. 10 is a diagram based on the image captured by the first line camera 11. The diagram illustrated in part B of Fig. 10 is a diagram based on the image captured by the second line camera 12. The diagram illustrated in part C of Fig. 10 is a diagram based on the image captured by the first line camera 11. The diagram illustrated in part D of Fig. 10 is a diagram based on the image captured by the second line camera 12. The horizontal axis of each diagram represents the pixel number (pix) of the line camera and the vertical axis of each diagram represents time (ms). As illustrated in Fig. 10, the matching for the wires partially having the sliding surface 8 can be performed.

[0064]

Moreover, Fig. 11 is a schematic view illustrating a state where the railroad car 10 passes a crossover installation in which the main wire 1 and the crossover wire 4 intersect. Note that the crossover wire 4 is suspended from a messenger wire 4a like the main wire 1 (and the secondary main wire 2 described above).

[0065]

Fig. 12 illustrates example views of captured images of the crossover installation illustrated in Fig. 11. The view illustrated part A of Fig. 12 is a view of the image captured by the first line camera 11 and the view illustrated part B of Fig. 12 is a view of the image captured by the second line camera 12. The horizontal axis of each view represents the pixel (pix) of the camera and the vertical axis of each view represents time (ms).

[0066]

In the crossover installation, the crossover wire 4 which is the measurement target wire sometimes do not have the sliding surface 8 as illustrated in Fig. 12. Accordingly, in the case of measuring the crossover wire 4, the wire measurement device utilizes information on time at which the wire having no sliding surface 8 and the wire having the sliding surface 8 intersect each other.

[0067]

Candidates of wires which intersect the wire (main wire 1) having the sliding surface data include not only the crossover wire 4 but also the messenger wire 4a of the crossover wire and the like as illustrated in Fig. 12. These wires intersect the wire having the sliding surface data at a portion A and a portion B in the view illustrated in part A of the Fig. 12 which is the image captured by the first line camera 11 and at a portion C and a portion D in the view illustrated part B of the Fig. 12 which is the image captured by the second line camera 12. However, this fact alone is insufficient for performing matching for the crossover wire 4 between the captured images.

[0068]

The crossover wire 4 has such a characteristic that, in the intersection between the crossover wire 4 and the main wire 1 in the crossover installation, the crossover wire 4 intersect the main wire 1 at approximately the same height as that of the main wire 1, and the information on the time of intersecting the wire having the sliding surface 8 is almost the same between the captured images. Accordingly, it is found that the wire having the intersection in the portion B in the view illustrated part A of the Fig. 12 which is the image captured by the first line camera 11 and the wire having the intersection in the portion C in the view illustrated part B of the Fig. 12 which is the image captured by the second line camera 12 are the crossover wire 4. If the crossover wire 4 is registered as one contact wire, the matching for the crossover wire 4 can be also performed.

[0069]

Fig. 13 includes data diagrams illustrating matching results of the main wire 1 and the crossover wire 4 in the crossover installation. The diagram illustrated in part A of Fig. 13 is a data diagram illustrating the matching result of the main wire 1 based on the image captured by the first line camera 11. The diagram illustrated in part B of Fig. 13 is a data diagram illustrating the matching result of the main wire 1 based on the image captured by the second line camera 12. The diagram illustrated in part C of Fig. 13 is a data diagram illustrating the matching result of the crossover wire 4 based on the image captured by the first line camera 11. The diagram illustrated in part D of Fig. 13 is a data diagram illustrating the matching result of the crossover wire 4 based on the image captured by the second line camera 12. The horizontal axis of

each diagram represents the pixel number (pix) of the line camera and the vertical axis of each diagram represents time (ms).

[0070]

As describe above, the matching unit 18 performs matching for not only the main wire 1 but the crossover wire 4 as illustrated in the diagrams in parts A, B, C, and D of Fig. 13.

[0071]

To achieve this, the matching unit 18 changes the matching method as described above depending on the conditional branch of whether the measurement target is the crossover wire 4 or not (in other words, the conditional branch of whether the sliding surface data exists or not) and, when the measurement target is the crossover wire 4, performs the matching by using the sliding surface information (of the wire which has the sliding surface 8 and which intersects the crossover wire 4) and the time information of the intersection (between the crossover wire 4 and the contact wire which has the sliding surface 8 and which intersects the crossover wire 4).

That is the explanation of the matching unit 18.

[0072]

The stereo measuring unit 19 performs stereo measurement of the matched pieces of joined wire data in the image captured the first line camera 11 and the image captured by the second line camera 12, and calculates and outputs the height and deviation of each wire as illustrated in the graph of Fig. 14 depicting the contact wire measurement results. The height and deviation are calculated in a way similar to that described in the section from paragraph [0025] to paragraph [0028] of the aforementioned Patent Document 2.

[0073]

The storage unit 20 stores pieces of data. The installation data setting unit 21 is a unit for inputting installation information including: the type of each installation such as the crossover or the air section; and the direction of each installation which is information on whether a second contact wire (contact wire other than the main wire) enters from left or right with respect to the traveling direction.

[0074]

Fig. 15 is a flowchart explaining operations of the entire image processing unit 9. Fig. 16 is a flowchart explaining operations of the matching unit 18 in detail. Operation steps of the image processing unit 9 are described below by using the flowcharts of Figs. 15, 16.

[0075]

As illustrated in Fig. 15, in step S1, the image inputting unit 14 obtains the image data captured by the first line camera 11 and the image data captured by the second line camera 12.

[0076]

In step S2, the sliding surface extracting unit 15 detects the sliding surface data.

[0077]

In step S3, the wire extracting unit 16 detects the wire point cloud data.

[0078]

In step S4, the joining unit 17 creates the joined wire data from the pieces of wire point cloud data.

[0079]

In step S5, the matching unit 18 matches the pieces of

joined wire data in the image captured by the first line camera 11 and the image captured by the second line camera 12.

[0080]

Step S5 is described in detail. As illustrated in Fig. 16, step S5 includes steps S5-1 to S5-3 described below.

[0081]

In step S5-1, the matching unit 18 determines whether the measurement targets are the crossover wire 4 or not (in other words, the condition branching of whether the sliding surface data exists or not). When the measurement targets are the crossover wire 4 (in other words, no sliding surface data exists), the processing proceeds to step S5-3. When the measurement targets are not the crossover wire 4 (in other words, the sliding surface data exists), the processing proceeds to step S5-2.

[0082]

In step S5-2, the matching unit 18 matches the pieces of joined wire data only by using the sliding surface information of the crossover wire 4 (measurement target wire).

[0083]

In step S5-3, the matching unit 18 matches the pieces of joined wire data by using the sliding surface information of the contact wire which has the sliding surface 8 and which intersects the crossover wire 4 and the time information of the intersection between this contact wire and the crossover wire 4.

[0084]

As illustrated in Fig. 15, in subsequent step S6, the stereo measuring unit 19 performs the stereo measurement of the matched pieces of joined wire data in the images captured by

the first line camera 11 and the second line camera 12 and calculates the height and deviation of the wire.

[0085]

In step S7, the calculated height and deviation of the wire are outputted.

That is the description of the operations of the image processing unit 9.

[0086]

The aforementioned Patent Document 1 additionally requires the height information and cannot measure the position (height and deviation) of the contact wire by using only the line cameras. However, in the embodiment, the height and deviation of the wire can be measured by using only the line cameras and, furthermore, not only the main wire but also the second wire (contact wire other than the main wire) whose deviation from the railroad car center is within the range of ± 900 mm can be measured as the measurement targets.

[0087]

The aforementioned Patent Document 2 requires the laser sensor. Since the laser has such a characteristic that the detection rate and accuracy decrease in proportion to the measurement distance, the stereo measurement of the distant contact wires in the crossover, the air section, and the like is difficult. However, in the embodiment, the stereo measurement is performed by using only the line cameras. Accordingly, the detection rate and accuracy in the stereo measurement of the distant contact wires in the crossover, the air section, and the like are less likely to decrease. Moreover, the data obtaining cycle with the laser is 10 times or more slower than that of the line cameras and it is difficult to mount the

wire measurement device using the laser on a high-speed railroad car such as a commercial railroad car. However, in the embodiment, since the stereo measurement is performed by using only the line cameras, the wire measurement device can be mounted on a high-speed railroad car such as a commercial railroad car.

[0088]

In the aforementioned Japanese Patent Application Publication No. 2014-196032, the limit is imposed on the height to enable the measurement of the crossover wire with the height limit (condition: "the crossover wire is installed at the height of 30 mm or lower from the main wire). However, the position measurement using the method of imposing the limit on the height is difficult to perform for an installation with a complex structure and an installation whose portion deviating from the railroad car center by ± 900 mm is at a high position. However, in the embodiment, the measurement is possible as long as there is a correlation between the measurement target wire and the contact wire having the sliding surface information.

INDUSTRIAL APPLICABILITY

[0089]

The present invention is suitable as wire measurement device and method.

EXPLANATION OF THE REFERENCE NUMERALS

[0090]

- 1 main wire
- 1a messenger wire (of main wire)
- 2 secondary main wire
- 2a messenger wire (of secondary main wire)
- 3 track

- 4 crossover wire
- 4a messenger wire (of crossover wire)
- 5 feeder cable
- 6 electric pole
- 7 pull-off arm
- 8 sliding surface
- 9 image processing unit
- 10 railroad car
- 10a, 30a rooftop (of railroad car)
- 11, 31 first line camera
- 12, 32 second line camera
- 13 lighting
- 14 image inputting unit
- 15 sliding surface extracting unit
- 16 wire extracting unit
- 17 joining unit
- 18 matching unit
- 19 stereo measuring unit
- 20 storage unit
- 21 installation data setting unit
- 33 third line camera

CLAIMS

[Claim 1]

A wire measurement device characterized that the wire measurement device comprises:

a first line camera and a second line camera which are disposed at both ends of a rooftop of a railroad car in a railroad-tie direction to be tilted toward a center of the railroad car in the railroad-tie direction and which captures images of wires; and

an image processing unit which calculates height and deviation of a measurement target wire by detecting wire information and sliding surface information of the measurement target wire from the image captured by the first line camera and the image captured by the second line camera, and by performing matching for the measurement target wire between the captured images by using the wire information and the sliding surface information.

[Claim 2]

The wire measurement device according to claim 1, characterized in that when the sliding surface information do not exist in the measurement target wire, the image processing unit performs the matching by using information on time at which the measurement target wire intersects a contact wire having a sliding surface and the sliding surface information of the contact wire.

[Claim 3]

The wire measurement device according to claim 2, characterized in that the image processing unit includes:

a sliding surface extracting unit which detects the sliding surface information from the image captured by the first

line camera and the image captured by the second line camera;

a wire extracting unit which detects the wire information from each of the image captured by the first line camera and the image captured by the second line camera;

a joining unit which creates joined wire information from the wire information;

a matching unit which performs the matching by using the sliding surface information when the sliding surface information exists in the measurement target wire and which performs the matching by using the information on time at which the measurement target wire intersects the contact wire having the sliding surface and the sliding surface information of the contact wire when the sliding surface information does not exist in the measurement target wire; and

a stereo measuring unit which calculates the height and deviation of the measurement target wire by performing stereo measurement of matched pieces of joined wire information out of pieces of the joined wire information in the image captured by the first line camera and the image captured by the second line camera.

[Claim 4]

A wire measurement method, characterized in that the wire measurement method comprises:

disposing a first line camera and a second line camera which captures images of wires at both ends of a rooftop of a railroad car in a railroad-tie direction such that the first line camera and the second line camera are tilted toward a center of the railroad car in the railroad-tie direction; and

calculating height and deviation of a measurement target wire by detecting wire information and sliding surface

information of the measurement target wire from the image captured by the first line camera and the image captured by the second line camera, and by performing matching for the measurement target wire between the captured images by using the wire information and the sliding surface information.

[Claim 5]

The wire measurement method according to claim 4, characterized in that the wire measurement method comprises:

when the sliding surface information do not exist in the measurement target wire, performing the matching by using information on time at which the measurement target wire intersects a contact wire having the sliding surface and the sliding surface information of the contact wire.

[Claim 6]

The wire measurement method according to claim 5, characterized in that the wire measurement method comprises:

detecting the sliding surface information from the image captured by the first line camera and the image captured by the second line camera,

detecting the wire information from the image captured by the first line camera and the image captured by the second line camera,

creating joined wire information from the wire information,

performing the matching by using the sliding surface information when the sliding surface information exists in the measurement target wire and performing the matching by using the information on time at which the measurement target wire intersects the contact wire having the sliding surface and the sliding surface information of the contact wire when the sliding

surface information does not exist in the measurement target wire,

calculating the height and deviation of the measurement target wire by performing stereo measurement of matched pieces of joined wire information out of pieces of the joined wire information in the image captured by the first line camera and the image captured by the second line camera.