MONITORING DEVICE, MONITORING METHOD, AND PROGRAM

Technical Field

[0001]

The present disclosure relates to a monitoring device, a monitoring method, and a program.

Background Art

[0002]

For example, in monitoring the states of a vehicle and a track by attaching an accelerometer to the vehicle and acquiring acceleration data during travel, it is required to identify a position of the vehicle with high accuracy. Patent Document 1 describes an example of a train position identifying method. The train position identifying method described in Patent Document 1 includes a step of acquiring measured curvature data, a step of extracting a portion of stored curvature data whose degree of deviation from the measured curvature data is minimal and acquiring the degree of deviation of the extracted portion from the measured curvature data as the minimum value of the degree of deviation, a step of identifying a train position based on a distance position in the portion whose degree of deviation is minimal when the minimum value of the degree of deviation is equal to or less than a threshold value or identifying the train position based on a travel distance calculated from a travel speed acquired based on an axle rotational speed when the minimum value of the degree of deviation exceeds the threshold value. That is, in the train position identifying method described in Patent Document 1, the position is identified based on a curvature collation result in a section in which collation between the stored curvature data and the measured curvature data is easy, or the position is identified based on the axle rotational speed in a section in which the collation is not easy.

Citation List

Patent Literature

[0003]

Patent Document 1: JP 2020-19333 A

Summary of Invention

Technical Problem

[0004]

In identifying a position using the train position identifying method described in Patent Document 1, the position is identified based on the axle rotational speed in a section in which the position is not easily identified based on the curvature collation result. For this reason, in a section in which the position is not easily identified based on the curvature collation result, the position cannot be identified with high accuracy, for example, when it is difficult to grasp an accurate position based on the integral of the axle rotational speed due to an error in a distance per rotation of the axle, a slip of a wheel, or the like. In the case where the position cannot be identified with high accuracy, there is a problem in that, for example, when measurement values are monitored by comparison with a reference value, the measurement values cannot be appropriately monitored.

[0005]

The present disclosure has been made to solve the problem described above, and an object of the present disclosure is to provide a monitoring device, a monitoring method, and a program that are capable of appropriately monitoring measurement values.

Solution to Problem

[0006]

In order to solve the problem described above, a monitoring device according to the present disclosure includes a non-linear expansion/contraction unit configured to non-linearly expand or contract a measured waveform based on distances between respective measurement values of the measured waveform and respective reference measurement values of a reference waveform, and a determination unit configured to determine whether or not there is an abnormality in the measured waveform based on a predetermined value obtained by non-linearly expanding or contracting the measured waveform.

[0007]

A monitoring method according to the present disclosure includes non-linearly expanding or contracting a measured waveform based on distances between respective measurement values of the measured waveform and respective reference measurement values of a reference waveform, and determining whether or not there is an abnormality in the measured waveform based on a predetermined value obtained by non-linearly expanding or contracting the measured waveform.

[0008]

A program according to the present disclosure causes a computer to execute non-linearly expanding or contracting a measured waveform based on distances between respective measurement values of the measured waveform and respective reference measurement values of a reference waveform, and determining whether or not there is an abnormality in the measured waveform based on a predetermined value obtained by non-linearly expanding or contracting the measured waveform.

Advantageous Effects of Invention

[0009]

According to the monitoring device, the monitoring method, and the program of the present disclosure, measurement values can be appropriately monitored.

Brief Description of Drawings

[0010]

FIG. 1 is a block diagram for describing a configuration example of an acceleration monitoring device according to a first embodiment of the present disclosure.

FIG. 2 is a side view illustrating an installation example of accelerometers 32 (accelerometers 32a to 32c) at vehicles 3 (vehicles 3a to 3c) illustrated in FIG. 1.

FIG. 3 is a plan view schematically illustrating a configuration example of a track according to an embodiment of the present disclosure.

FIG. 4 is a schematic view illustrating a configuration example of a reference acceleration waveform database 261 illustrated in FIG. 1.

FIG. 5 is a schematic view illustrating a configuration example of a measured acceleration waveform database 263 illustrated in FIG. 1.

FIG. 6 is a schematic view for describing an operation example of an acceleration monitoring device according to an embodiment of the present disclosure.

FIG. 7 is a schematic view illustrating a configuration example of a monitoring result database 265 illustrated in FIG. 1.

FIG. 8 is a flowchart illustrating an operation example of the acceleration monitoring device according to the first embodiment of the present disclosure.

FIG. 9 is a schematic view for describing an operation example of the acceleration monitoring device according to the first embodiment of the present disclosure.

FIG. 10 is a flowchart illustrating an operation example of an acceleration monitoring device according to a second embodiment of the present disclosure.

FIG. 11 is a block diagram illustrating a configuration example of an acceleration monitoring device according to a third embodiment of the present disclosure.

FIG. 12 is a schematic view illustrating a configuration example of a measured acceleration waveform database according to the third embodiment of the present disclosure.

FIG. 13 is a flowchart illustrating an operation example of the acceleration monitoring device according to the third embodiment of the present disclosure.

FIG. 14 is a schematic view for describing an operation example of the acceleration monitoring device according to the third embodiment of the present disclosure.

FIG. 15 is a waveform chart for describing an operational effect of an acceleration monitoring device according to an embodiment of the present disclosure.

FIG. 16 is a waveform chart (comparison example) for describing an operational effect of an acceleration monitoring device according to an embodiment of the present disclosure.

FIG. 17 is a schematic block diagram illustrating a configuration of a computer according to at least one embodiment.

Description of Embodiments

[0011]

A monitoring device, a monitoring method, and a program according to each of embodiments of the present disclosure will be described below with reference to the accompanying drawings. Note that, in the drawings, the same reference signs are used for the same or corresponding configurations, and description thereof will not be repeated as appropriate.

[0012]

First Embodiment

A monitoring device, a monitoring method, and a program according to a first embodiment of the present disclosure will be described below with

reference to FIGS. 1 to 9, FIG. 15, and FIG. 16. FIG. 1 is a block diagram for describing a configuration example of the acceleration monitoring device according to the first embodiment of the present disclosure. FIG. 2 is a side view illustrating an installation example of accelerometers 32 (accelerometers 32a to 32c) at vehicles 3 (vehicles 3a to 3c) illustrated in FIG. 1. FIG. 3 is a plan view schematically illustrating a configuration example of a track according to an embodiment of the present disclosure. FIG. 4 is a schematic view illustrating a configuration example of a reference acceleration waveform database 261 illustrated in FIG. 1. FIG. 5 is a schematic view illustrating a configuration example of a measured acceleration waveform database 263 illustrated in FIG. 1. FIG. 6 is a schematic view for describing an operation example of an acceleration monitoring device according to an embodiment of the present disclosure. FIG. 7 is a schematic view illustrating a configuration example of a monitoring result database 265 illustrated in FIG. 1. FIG. 8 is a flowchart illustrating an operation example of the acceleration monitoring device according to the first embodiment of the present disclosure. FIG. 9 is a schematic view for describing an operation example of the acceleration monitoring device according to the first embodiment of the present disclosure. FIG. 15 is a waveform chart for describing an operational effect of an acceleration monitoring device according to an embodiment of the present disclosure. FIG. 16 is a waveform chart (comparison example) for describing an operational effect of an acceleration monitoring device according to an embodiment of the present disclosure.

[0013]

Configuration of Acceleration Monitoring Device 2

An acceleration monitoring device 2 illustrated in FIG. 1 is a configuration example of a monitoring device according to the present disclosure. The acceleration monitoring device 2 is an example of a monitoring device in a case where a measured waveform according to the present disclosure is an acceleration waveform measured in a vehicle traveling on a track. However, the measured waveform according to the present disclosure is not limited to the acceleration waveform measured in the vehicle traveling on the track. The monitoring device of the present disclosure can be applied to a general measured waveform that is time series of measurement values.

[0014]

The acceleration monitoring device 2 is configured as a component of an automated guideway transit (AGT) 1, for example. The automated guideway transit 1 illustrated in FIG. 1 includes, for example, the acceleration monitoring

device 2, a plurality of vehicles 3, a plurality of ground devices 4, and an operation management device 5.

[0015]

The operation management device 5 is a device that controls the operations of a plurality of trains each including the plurality of vehicles 3, and transmits and receives predetermined control signals to and from the vehicles 3 via the ground devices 4. The ground devices 4 relay, for example, communication between the operation management device 5 and the vehicles 3.

[0016]

In the present embodiment, the vehicle 3 travels on a track T1 illustrated in FIG. 3 as an example. The track T1 includes two driving lanes DL1 and DL2 in which a driving direction is defined. The track T1 is provided with a station ST1 and a station ST2. In this case, a section from the station ST1 to the station ST2 constitutes one section SEC1. In the track T1, a region of interest RI1 and a region of interest RI2, which are partial regions of the track T1, are defined in advance. In the present embodiment, the region of interest is a region in which generated accelerations are to be monitored. In the example illustrated in FIG. 3, the region of interest RI1 and the region of interest RI2 are a region surrounding an expansion joint EJ1 and a region surrounding an expansion joint EJ2, respectively. In the track T1, relatively large accelerations are generated at bumps such as the expansion joints and at branching positions (not illustrated).

[0017]

As illustrated in FIG. 1, the vehicle 3 includes an on-board device 31, one or more accelerometers 32, and a position identification information acquisition device 33. The on-board device 31 includes a control unit 311, a storage unit 312, and a communication unit 313 as functional configurations formed by combining hardware and software.

[0018]

In the on-board device 31, the control unit 311 automatically controls a power source such as a motor, a steering device, a boarding device, and the like (not illustrated) of the vehicle 3 based on control signals received by the communication unit 313 from the operation management device 5 via the ground device 4. Further, the control unit 311 acquires accelerations detected by the accelerometers 32 at a predetermined sampling period, stores the accelerations in the storage unit 312, and causes the communication unit 313 to transmit the accelerations to the operation management device 5 via the ground device 4 at a predetermined timing. Furthermore, the control unit 311 acquires position identification information identified by the position identification

information acquisition device 33 at a predetermined sampling period, stores the position identification information in the storage unit 312, and causes the communication unit 313 to transmit the position identification information to the operation management device 5 via the ground device 4 at a predetermined timing. For example, the on-board device 31 collectively transmits time series data output by the accelerometers 32 and time series data output by the position identification information acquisition device 33, which have been acquired in one section between stations, to the operation management device 5 via the ground device 4 at the time of arrival at a station. However, the transmission timing of the acceleration data and the position identification information is not limited to the above-described case.

[0019]

The accelerometer 32 detects, for example, accelerations in three axes, and outputs the detection result to the control unit 311. The position identification information acquisition device 33 acquires information for identifying the position of the vehicle 3 and outputs the information to the control unit 311. The position identification information acquisition device 33 acquires, for example, signals corresponding to the rotational speed of tires 302 (FIG. 2) of the vehicle 3 and outputs the signals indicating the speed of the vehicle 3 as the position identification information. Alternatively, the position identification information acquisition device 33 acquires a latitude and a longitude representing a current position obtained by receiving radio waves emitted by an artificial satellite of a global positioning system (GPS), and outputs the latitude and the longitude as the position identification information.

[0020]

The plurality of accelerometers 32 may be attached to each of the vehicles 3a to 3c constituting a train 30 as the accelerometers 32a to 32c as illustrated in FIG. 2. In the example illustrated in FIG. 2, the accelerometer 32a and the accelerometer 32c are attached to two bogies 303 of each of the vehicles 3a to 3c. In addition, the accelerometer 32b is attached to a vehicle body 301 of each of the vehicles 3a to 3c. In this case, the accelerometers 32a to 32c detect, for example, accelerations in three axes of front-back, left-right, and up-down directions, and output signals indicating the accelerations detected. However, accelerations to be measured are not limited to accelerations in all the three directions, but may be accelerations in any one or two directions. Note that the bogie 303 rotatably supports the rubber tires 302 and is mounted to the vehicle body 301 via a shock absorber 304 such as an air spring. In the example illustrated in FIG. 2, the on-board device 31 and the

position identification information acquisition device 33 are provided in the vehicle 3a.

[0021]

On the other hand, the acceleration monitoring device 2 includes, for example, a computer, and a peripheral device and a peripheral circuit of the computer, and includes each of the following units as a functional configuration formed by combining hardware such as a computer and software such as a program executed by the computer. That is, the acceleration monitoring device 2 includes, as functional configurations, a control unit 21, a communication unit 22, an acquisition unit 23, a monitoring unit 24, a database management unit 25, and a storage unit 26. The monitoring unit 24 includes a non-linear expansion/contraction unit 241 and a determination unit 242.

[0022]

The storage unit 26 stores a reference acceleration waveform database 261, a plurality of reference acceleration waveform files 262, a measured acceleration waveform database 263, a plurality of measured acceleration waveform files 264, and a monitoring result database 265.

[0023]

The reference acceleration waveform database 261 is information for managing information related to a reference acceleration waveform that is an acceleration waveform serving as a reference for a measured acceleration waveform that is an acceleration waveform newly measured in each vehicle 3 that is a monitoring target. The reference acceleration waveform is, for example, an acceleration waveform measured in the vehicle 3 of a standard type in each region of interest (region of interest RI1, region of interest RI2, and the like). FIG. 4 illustrates a configuration example of the reference acceleration waveform database 261. The reference acceleration waveform database 261 illustrated in FIG. 4 stores a region-of-interest identification code, a vehicle identification code, a section identification code, a driving lane identification code, an accelerometer identification code, a measurement position, a measurement direction, a positive peak/ negative peak/effective values, and a reference acceleration waveform file name in association with one another. The region-of-interest identification code is a code for uniquely identifying the region of interest illustrated in FIG. 3. The vehicle identification code is a code for uniquely identifying the vehicle 3 whose reference acceleration waveform has been measured. The section identification code is a code for uniquely identifying a section in which the region of interest is located. The driving lane identification code is a code for uniquely

identifying a driving lane on which the measured vehicle 3 has traveled. The accelerometer identification code is a code for identifying, uniquely or for each vehicle 3, the accelerometer 32 having performed a measurement. The measurement position indicates whether a measurement position is closer to a vehicle body (above the spring) or closer to a bogie (below the spring) than the shock absorber 304 (spring). The measurement direction indicates whether an acceleration direction is an up-down direction, a front-back direction, or a left-right direction. The positive peak/negative peak/effective values are a positive peak value, a negative peak value, and an effective value of a reference acceleration waveform. The reference acceleration waveform file name is a name of the reference acceleration waveform file 262 indicating a reference acceleration waveform. The row C1 of the reference acceleration waveform database 261 illustrated in FIG. 4 corresponds to, for example, a reference acceleration waveform AWB1 (file name "FB001") measured in the region of interest RI1 illustrated in FIG. 3. The row C2 of the reference acceleration waveform database 261 illustrated in FIG. 4 corresponds to, for example, a reference acceleration waveform AWB2 (file name "FB201") measured in the region of interest RI2 illustrated in FIG. 3.

[0024]

The reference acceleration waveform file 262 is a file indicating a reference acceleration waveform measured in each of the regions of interest RI1 and RI2, and the like. In the present embodiment, a measurement value included in a reference acceleration waveform is also referred to as a reference measurement value. In this case, the reference acceleration waveform is the time series of reference measurement values.

[0025]

The measured acceleration waveform database 263 is, for example, information for managing information related to a measured acceleration waveform that is an acceleration waveform measured for each section (for each section SEC1 or the like) in each vehicle 3 that is a monitoring target. FIG. 5 illustrates a configuration example of the measured acceleration waveform database 263. The measured acceleration waveform database 263 illustrated in FIG. 5 stores a measurement date and time (year, month, day, hour, minute, and second), a vehicle identification code, a section identification code, a driving lane identification code, an accelerometer identification code, a measurement position, a measurement direction, travel start/end times, and a measured acceleration waveform file name in association with one another. The vehicle identification code, the section identification code, the driving lane

identification code, the accelerometer identification code, the measurement position, and the measurement direction are identical to the corresponding items of the reference acceleration waveform database 261. The travel start/end times are a travel start time (date and time) and a travel end time (date and time) of a section concerned. The measured acceleration waveform file name is a name of the measured acceleration waveform file 264 indicating a measured acceleration waveform. For example, the name of the file indicating a measured acceleration waveform AWM1 illustrated in FIG. 6, which is measured in the section SEC1 is "FM001".

[0026]

The measured acceleration waveform file 264 is a file indicating a measured acceleration waveform measured in the vehicle 3 that is a monitoring target. The measured acceleration waveform is the time series of measurement values.

[0027]

The monitoring result database 265 is information obtained by summarizing the monitoring result (or the evaluation result) of acceleration values (peak values, effective values, and the like) based on a measured acceleration waveform newly measured in each region of interest (region of interest RI1, region of interest RI2, and the like). FIG. 7 illustrates a configuration example of the monitoring result database 265. The monitoring result database 265 illustrated in FIG. 7 stores a region-of-interest identification code, a driving lane identification code, a vehicle identification code, a measurement date and time, an accelerometer identification code, a measurement direction, and a monitoring result in association with one another. The region-of-interest identification code, the driving lane identification code, the vehicle identification code, the accelerometer identification code, and the measurement direction are identical to the corresponding items of the reference acceleration waveform database 261. In this example, the monitoring result includes a positive peak value, a negative peak value, and an effective value measured in a region of interest.

[0028]

The control unit 21 controls the respective units 22 to 26. The communication unit 22 receives, for example, an acceleration waveform that is the time series data of accelerations measured in the vehicle 3 from the operation management device 5, for example, for each section SEC1 in accordance with an instruction from the control unit 21 (or the acquisition unit 23). Note that the time series data of accelerations is time-series data of

measured acceleration values, and is, for example, a measured acceleration waveform. However, the communication unit 22 may receive, for example, an acceleration waveform measured in the vehicle 3 directly from the vehicle 3, for example, for each section SEC1 in accordance with an instruction from the control unit 21 (or the acquisition unit 23). FIG. 6 illustrates an example of the measured acceleration waveform AWM1. For example, the control unit 21 (or the acquisition unit 23) acquires (a file including data indicating) the measured acceleration waveform AWM1 from the operation management device 5 and stores the measured acceleration waveform AWM1 in the storage unit 26 as the measured acceleration waveform file 264. Further, the control unit 21 (or the acquisition unit 23) registers, in the measured acceleration waveform database 263, information about the measured acceleration waveform file 264 stored. Note that the control unit 21 (or the acquisition unit 23) can acquire the following information when acquiring, for example, the measured acceleration waveform AWM1 from the operation management device 5. That is, the control unit 21 (or the acquisition unit 23) can acquire the measurement date and time of the measured acceleration waveform AWM1, the identification code of the vehicle 3 measured, the identification code of the section SEC1 measured, the identification code of a driving lane, the identification code of the accelerometer 32 having performed measurement, the information indicating an acceleration direction, the information indicating travel start and end times, and the time series data of position identification information corresponding to the measured acceleration waveform AWM1.

[0029]

The acquisition unit 23 acquires a measured acceleration waveform (the measured acceleration waveform file 264), which is an acceleration waveform measured in the vehicle 3 traveling on the track T1, to be monitored (evaluated), for example, from the storage unit 26 (or from the vehicles 3).

[0030]

The monitoring unit 24 monitors acceleration values of a non-linearly expanded/contracted measured acceleration waveform that is an acceleration waveform made to correspond to a reference acceleration waveform by non-linearly expanding or contracting a time axis of a measured acceleration waveform. At this time, in the monitoring unit 24, the non-linear expansion/contraction unit 241 non-linearly expands or contracts the time axis of the measured acceleration waveform based on a distance between each measurement value of the measured acceleration waveform and each reference measurement value of the reference acceleration waveform. The determination

unit 242 determines whether or not there is an abnormality in the measured acceleration waveform based on a predetermined value obtained by non-linearly expanding or contracting the measured acceleration waveform.

[0031]

For example, when an acceleration value (a maximum value or an effective value) in each predetermined section of a measured acceleration waveform measured in the first vehicle 3 exceeds a predetermined threshold value for each section, the monitoring unit 24 determines whether or not there is an abnormality in the first vehicle 3 or an abnormality in the track T1 in the following manner. That is, the monitoring unit 24 determines whether or not there is an abnormality in the first vehicle 3 or an abnormality in the track T1 based on the comparison result between an acceleration value (a maximum value or an effective value) in each section of a measured acceleration waveform measured in the second vehicle 3 that is different from the first vehicle 3 and a threshold value for each section.

[0032]

During monitoring, first, the monitoring unit 24 causes the non-linear expansion/contraction unit 241 to non-linearly expand or contract the time axis of a measured acceleration waveform, which is a monitoring target, by matching processing with a reference acceleration waveform that is an acceleration waveform serving as a reference. The matching processing is processing for minimizing a distance between two pieces of time series data of the measured acceleration waveform and the reference acceleration waveform so as to increase a correlation coefficient between the two pieces of time-series data. The non-linear expansion/contraction unit 241 acquires a non-linearly expanded/contracted measured acceleration waveform that is an acceleration waveform made to correspond to the reference acceleration waveform by non-linearly expanding or contracting the time axis of the measured acceleration waveform. The non-linear expansion/contraction unit 241 acquires, for example, a non-linearly expanded/contracted measured acceleration waveform AWM1P1c and a non-linearly expanded/contracted measured acceleration waveform AWM1P2c illustrated in FIG. 6 by the matching processing between, for example, the measured acceleration waveform AWM1 illustrated in FIG. 6 and, for example, the reference acceleration waveform AWB1 and the reference acceleration waveform AWB2 illustrated in FIG. 3. As a method of increasing a correlation coefficient between waveforms by non-linear expansion/contraction, there are methods such as dynamic programming (DP) matching (a matching method using a dynamic programming method) and

dynamic time warping. The DP matching or the dynamic time warping is a technique for non-linearly expanding or contracting waveforms so as to minimize a distance between corresponding points of two waveforms, and the distance is defined by the sum of squares of the distance ($\Sigma(xi - yi)^2$), the sum of absolute values of differences ($\Sigma|xi - yi|$), or the like. Where xi and yi are each reference measurement value of the reference waveform and each measurement value of the measured waveform, respectively. Note that the non-linearly expanded/contracted measured acceleration waveform AWM1P1c is an acceleration waveform made to correspond to the reference acceleration waveform AWB1 by non-linearly expanding or contracting the time axis of an acceleration waveform AWM1P1 that is a part of the measured acceleration waveform AWM1. The non-linearly expanded/contracted measured acceleration waveform AWM1P2c is an acceleration waveform made to correspond to the reference acceleration waveform AWB2 by non-linearly expanding or contracting the time axis of an acceleration waveform AWM1P2 that is a part of the measured acceleration waveform AWM1.

[0033]

Next, the determination unit 242 determines whether or not there is an abnormality in the measured acceleration waveform based on a predetermined value obtained by non-linearly expanding or contracting the measured acceleration waveform. In the present embodiment, the predetermined value is the expansion/contraction amount of each measurement value of the measured acceleration waveform that have been non-linearly expanded or contracted. The determination unit 242 determines that there is an abnormality in the measured acceleration waveform when there is any of the expansion/contraction amounts that is equal to or greater than a predetermined expansion/contraction amount threshold value. FIG. 9 schematically illustrates an example of the relationship among a reference acceleration waveform, a measured acceleration waveform, and a non-linearly expanded/contracted measured acceleration waveform. It is assumed that the reference acceleration waveform and the measured acceleration waveform illustrated in FIG. 9 are measured in the same section and on the same driving lane. The horizontal axis represents time and the vertical axis represents acceleration. However, the time in the horizontal axis may be replaced with a distance based on the measurement time of each measurement value and the speed information or the position information of the vehicle 3. In the example illustrated in FIG. 9, the reference acceleration waveform includes a peak P1 and a peak P3. The measured acceleration waveform includes a peak P11 corresponding to the peak P1, a peak P13

corresponding to the peak P3, and a new peak P12. The peak P12 corresponds to any abnormality that has occurred on the track T1, for example. In the non-linearly expanded/contracted measured acceleration waveform in the example illustrated in FIG. 9, the position on the time axis of a peak P12a corresponding to the peak P12 that is not present in the reference acceleration waveform is shifted toward the peak P11 by the DP matching. On the other hand, the positions on the time axis of a peak P11a corresponding to the peak P11 and a peak P13a corresponding to the peak P13 are not changed so much. In the example illustrated in FIG. 9, there is a possibility that the acceleration is erroneously evaluated due to large expansion/contraction in a time axis direction. Note that, in the present embodiment, a time difference between a measurement time t1 of a measurement point before the non-linear expansion/contraction and an expanded/contracted measurement time t2 of the same measurement point after the non-linear expansion/contraction is referred to as an expansion/contraction amount. When the horizontal axis represents distance, an expansion/contraction amount is a positional difference between the same measurement point before and after expansion/contraction. Hereinafter, an expansion/contraction amount in terms of a time difference is also referred to as a time axis expansion/contraction amount.

[0034]

As described above, the determination unit 242 determines whether or not an expansion/contraction amount of each measurement value of the non-linearly expanded/contracted measured acceleration waveform is equal to or greater than a predetermined expansion/contraction amount threshold value. Then, when there is an expansion/contraction amount equal to or greater than the expansion/contraction amount threshold value, the monitoring unit 24 determines that, for example, the state of the track has been largely changed, and determines that an abnormality has occurred in the track or the vehicle without executing an evaluation by the DP matching. The monitoring unit 24 executes the same processing on the plurality of vehicles 3, and determines that an abnormality has occurred in the track T1 when determining that an expansion/contraction amount is abnormal as described above also in the plurality of vehicles 3 through the analysis of a certain section. When it is determined that an abnormality has occurred in a certain vehicle 3 alone, the monitoring unit 24 determines that the abnormality has occurred in that vehicle 3.

[0035]

Note that the expansion/contraction amount threshold value may be, for example, a distance between a front wheel and a rear wheel of the vehicle 3 (wheelbase) or a time obtained by dividing the distance by a speed. Large accelerations are generated when the front wheel and the rear wheel pass through a position of an expansion joint (EJ) of the track T1. However, when peaks at which the large accelerations are generated are separated from each other by the expansion/contraction amount threshold value or greater, it can be determined that an abnormality has occurred at any portion other than the target EJ in the track.

[0036]

When the determination unit 242 determines that the expansion/contraction amount of each measurement value of the non-linearly expanded/contracted measured acceleration waveform is not equal to or greater than the predetermined expansion/contraction amount threshold value, the monitoring unit 24 monitors (evaluates) the acceleration values of the non-linearly expanded/contracted measured acceleration waveform (for example, the non-linearly expanded/contracted measured acceleration waveform AWM1P1c and the non-linearly expanded/contracted measured acceleration waveform AWM1P2c in FIG. 6). At this time, the monitoring unit 24 acquires, for example, a maximum value P11 of the positive peak values, a maximum value P12 of the negative peak values, and the effective value of the non-linearly expanded/contracted measured acceleration waveform AWM1P1c illustrated in FIG. 6, and registers these values in the monitoring result database 265. Also, the monitoring unit 24 acquires a maximum value P21 of the positive peak values, a maximum value P22 of the negative peak values, and the effective value of the non-linearly expanded/contracted measured acceleration waveform AWM1P2c illustrated in FIG. 6, and registers these values in the monitoring result database 265. Further, the monitoring unit 24 determines the presence or absence of an abnormality by, for example, comparison with the reference acceleration waveform AWB1 and the reference acceleration waveform AWB2, comparison with a measured acceleration waveform of the same vehicle 3 or another vehicle 3, or comparison with a predetermined threshold value.

[0037]

The database management unit 25 creates or changes the reference acceleration waveform database 261, searches for, displays, or prints data registered in the monitoring result database 265, for example, in accordance with a predetermined input operation by an operator.

[0038]

Operation Example of Acceleration Monitoring Device 2

Next, an operation example of the acceleration monitoring device 2 illustrated in FIG. 1 will be described with reference to FIG. 8. FIG. 8 illustrates an example of processing of creating the reference acceleration waveform database 261 (S101 to S103) and an example of processing in monitoring a measured acceleration waveform (S201 to S212).

[0039]

As illustrated in FIG. 8, in creating the reference acceleration waveform database 261, a reference acceleration waveform for each vehicle, each driving lane, and each measurement position/direction is first acquired from the vehicles 3 offline (or online via the operation management device 5 or the like) by using the communication unit 22 and the acquisition unit 23 (step S101). Next, positions of peaks of an acceleration waveform are associated with the regions of interest by using the database management unit 25 (step S102). Then, the database of the reference acceleration waveforms is created by using the database management unit 25 (step S103).

[0040]

As illustrated in FIG. 8, in monitoring a measured acceleration waveform, the monitoring unit 24 specifies vehicle information (step S201) and acquires acceleration data of the vehicle 3 to be analyzed (step S202), and the non-linear expansion/contraction unit 241 executes DP matching between a plurality of reference acceleration waveforms in the reference acceleration waveform database 261 and the measured acceleration waveform acquired (step S203).

[0041]

Next, the determination unit 242 determines whether or not the time axis expansion/contraction amount at the DP matching is equal to or greater than an expansion/contraction amount threshold value (step S204). When the time axis expansion/contraction amount at the DP matching is equal to or greater than the expansion/contraction amount threshold value (step S204: Yes), the determination unit 242 determines whether or not the time axis expansion/contraction amount is equal to or greater than the expansion/contraction amount threshold value in a certain vehicle alone (step S206). When the time axis expansion/contraction amount is equal to or greater than the expansion/contraction amount threshold value in a certain vehicle alone (step S206: Yes), the determination unit 242 determines that an abnormality has occurred in the vehicle (step S207). When the time axis

expansion/contraction amount is not equal to or greater than the expansion/contraction amount threshold value in a certain vehicle alone (step S206: No), the determination unit 242 determines that an abnormality has occurred in a target section in the track (step S208).

[0042]

On the other hand, when the time axis expansion/contraction amount at the DP matching is not equal to or greater than the expansion/contraction amount threshold value (step S204: No), the monitoring unit 24 identifies an acceleration waveform corresponding to a region of interest included in the measured acceleration waveform, and executes abnormality detection by monitoring acceleration values (step S205).

[0043]

In addition, the monitoring unit 24 evaluates a maximum value and an effective value for each section (step S209), and compares the maximum value and the effective value with an evaluation result (D201) of a maximum value and an effective value for each section in other vehicles (step S10). Then, when the maximum value or the effective value is relatively large in a certain vehicle alone (step S210: Yes), the monitoring unit 24 determines that an abnormality has occurred in the certain vehicle (step S211). When the maximum value is not relatively large and the effective value is not relatively large in a certain vehicle alone (step S210: No), the monitoring unit 24 determines that an abnormality has occurred in a target section in the track (step S212).

[0044]

Supplementary Explanation, Operation, Effect, and the Like of First Embodiment

In the present embodiment, a measured acceleration waveform is non-linearly expanded or contracted based on a reference acceleration waveform. At this time, in the present embodiment, a limitation is imposed on a non-linear expansion/contraction amount. In the present embodiment, when a waveform needs to be expanded or contracted by a certain period of time (or a certain distance) or longer, the state of the track is determined to have been largely changed, and then it is determined that an abnormality has occurred in the track or the vehicle without performing an evaluation based on a non-linearly expanded/contracted measured acceleration.

[0045]

In addition, when the same processing is executed on a plurality of vehicles and the analysis of a certain section indicates that an expansion/contraction amount equal to or greater than the

expansion/contraction amount threshold value has been generated in the plurality of vehicles, it is determined that an abnormality has occurred in the track. When an abnormal expansion/contraction amount is determined to have been generated in a certain vehicle alone, it is determined that an abnormality has occurred in the vehicle.

[0046]

In executing non-linear expansion/contraction and involving extreme non-linear expansion/contraction of a time axis, an error may occur in the extraction of peaks of a waveform to be analyzed. In the present embodiment, when extreme non-linear expansion/contraction occurs, it can be determined that an abnormality of some kind has occurred, and thus monitoring is prevented from being continued without noticing the abnormality.

[0047]

In addition, by evaluating a maximum value and an effective value for each section (for example, between stations), it is possible to roughly determine the presence or absence of an abnormality in the entire section. In the present embodiment, by identifying a section in which non-linear expansion/contraction by a period of time (or a distance) equal to or greater than the expansion/contraction amount threshold value has occurred, it is possible to determine the presence or absence of an abnormality at a position that is not originally assumed. Further, by combining the evaluation based on a maximum value or an effective value and the evaluation based on an expansion/contraction amount, it is possible to determine an occurrence position of an abnormality that cannot be found only by section-by-section determination or acceleration extraction at a certain position by the matching, and thus the efficiency of state monitoring can be improved.

[0048]

As described above, according to the present embodiment, measurement values can be appropriately monitored.

[0049]

Note that FIG. 15 and FIG. 16 illustrate examples of acceleration waveforms in the case where the same vehicle travels ten times on the same track under the same speed conditions. FIG. 15 illustrates enlarged waveforms of a reference acceleration waveform and a non-linearly expanded/contracted measured acceleration waveform in the case where the DP matching is performed with a waveform of one travel out of ten travels used as the reference acceleration waveform. FIG. 16 illustrates enlarged waveforms in the vicinity of 56 seconds and in the vicinity of 64.4 seconds in the case where

waveforms of ten travels are matched in accordance with acceleration peaks in the vicinity of 56 seconds. In the example illustrated in FIG. 16, even when the timings of certain acceleration peak positions are adjusted to coincide with each other, the timings of other acceleration peak occurrence positions deviate from each other, and thus it takes time to perform evaluation. On the other hand, when the DP matching is performed, the acceleration peak occurrence positions are accurately associated with each other as illustrated in FIG. 15.

[0050]

Second Embodiment

An acceleration monitoring device according to a second embodiment of the present disclosure will be described below with reference to FIG. 10. FIG. 10 is a flowchart illustrating an operation example of the acceleration monitoring device according to the second embodiment of the present disclosure. The block configuration of the acceleration monitoring device according to the second embodiment is the same as the block configuration of the acceleration monitoring device 2 illustrated in FIG. 1. The acceleration monitoring device of the second embodiment differs partially from that of the first embodiment in terms of the operation of the determination unit 242 illustrated in FIG. 1. In the first embodiment, with a time axis expansion/contraction amount as a predetermined value according to the present disclosure, the determination unit 242 determines whether or not there is an abnormality in a measured acceleration waveform based on the time axis expansion/contraction amount. On the other hand, in the second embodiment, a correlation coefficient between a measured acceleration waveform that have been non-linearly expanded or contracted (non-linearly expanded/contracted measured acceleration waveform) and a reference acceleration waveform is used as a predetermined value according to the present disclosure, and the determination unit 242 determines that there is an abnormality in the measured acceleration waveform when the correlation coefficient is equal to or less than a predetermined correlation coefficient threshold value.

[0051]

The processing of the second embodiment illustrated in FIG. 10 differs from the processing of the first embodiment in terms of the processing in step S204a (corresponding to step S204 in FIG. 8) and the processing in step S206a (corresponding to step S206 in FIG. 8). In step S204a, the determination unit 242 determines whether or not a correlation coefficient after the DP matching is equal to or less than the correlation coefficient threshold value. In step S204a, the determination unit 242 determines whether or not a correlation coefficient

of a certain vehicle alone is equal to or less than the correlation coefficient threshold value.

[0052]

In the second embodiment, for example, after the non-linear expansion/contraction unit 241 executes the DP matching on the reference acceleration waveform and a measured acceleration waveform to be analyzed, the determination unit 242 of the second embodiment calculates a correlation coefficient between the matched waveforms. Then, when the correlation coefficient is larger than the correlation coefficient threshold value, the monitoring unit 24 determines that there is no significant change and continues the analysis. When the correlation coefficient is equal to or less than the correlation coefficient threshold value, the monitoring unit 24 determines that the state has been largely changed and determines that an abnormality has occurred without analyzing respective accelerations of monitoring target positions.

[0053]

Generally, under the same travel conditions, the correlation coefficient after the DP matching is at least 0.9. By determining that a large abnormality has occurred when the correlation coefficient becomes equal to or less than the value above, it is possible to determine that an abnormality has occurred before performing comparison with other data or the like.

[0054]

According to the second embodiment, measurement values can be appropriately monitored in a manner similar to the first embodiment.

[0055]

Third Embodiment

An acceleration monitoring device 2a according to a third embodiment of the present disclosure (corresponding to the acceleration monitoring device 2 of the first embodiment) will be described below with reference to FIGS. 11 to 14. FIG. 11 is a block diagram illustrating a configuration example of the acceleration monitoring device according to the third embodiment of the present disclosure. FIG. 12 is a schematic view illustrating a configuration example of a measured acceleration waveform database according to the third embodiment of the present disclosure. FIG. 13 is a flowchart illustrating an operation example of the acceleration monitoring device according to the third embodiment of the present disclosure. FIG. 14 is a schematic view for describing an operation example of the acceleration monitoring device according to the third embodiment of the present disclosure.

[0056]

In the acceleration monitoring device 2a according to the third embodiment illustrated in FIG. 11, a monitoring unit 24a (corresponding to the monitoring unit 24 in FIG. 1) additionally includes a position identification unit 243, as compared with the acceleration monitoring device 2 according to the first embodiment illustrated in FIG. 1. In addition, the configuration of a measured acceleration waveform database 263a (corresponding to the measured acceleration waveform database 263) stored in the storage unit 26 is partially different. The storage unit 26 further stores a plurality of position information files 266.

[0057]

The position information file 266 is a file including time series data of position identification information (hereinafter, also referred to as position information) identified by the position identification information acquisition device 33 of the vehicle 3. As described above, the position identification information is, for example, a time series of position information indicating a latitude and a longitude acquired using a global positioning system. The position information in the position information file 266 can be associated with each measurement value in the measured acceleration waveform file 264 by using information indicating a measurement time. However, the sampling period of accelerations is usually shorter than the sampling period of position information. In this case, the position information is associated with at least part of respective measurement values of the measured acceleration waveform.

[0058]

The measured acceleration waveform database 263a corresponds to the measured acceleration waveform database 263 illustrated in FIG. 1, and a position information file name, which is a file name of the position information file 266, is further associated with the measured acceleration waveform file name and the like as illustrated in FIG. 12.

[0059]

The position identification unit 243 identifies a position corresponding to a measurement value of a measured acceleration waveform having a time axis expansion/contraction amount equal to or greater than an expansion/contraction amount threshold value by using position information in the position information file 266. At this time, for example, as illustrated in FIG. 14, the position identification unit 243 identifies a position corresponding to a measurement value having a peak value (for example, P12) in a section including a plurality of measurement values having a time axis

expansion/contraction amount equal to or greater than the expansion/contraction amount threshold value. FIG. 14 illustrates a reference acceleration waveform, a measured acceleration waveform, and a non-linearly expanded/contracted measured acceleration waveform identical to those in FIG. 9.

[0060]

As described above, when the sampling time of position information is longer than the sampling time of acceleration data, the position identification unit 243 performs, for example, interpolation in order to match the position information with the sampling time of the acceleration data. Examples of an interpolation method include general linear interpolation using a one dimensional function and spline interpolation. By this processing, for example, GPS data acquired at a low sampling frequency is up-sampled, and thus GPS data on the same time axis as the acceleration can be obtained. The position identification unit 243 combines, with the above-described GPS data, a time at which a maximum acceleration value (absolute value) is generated in a time (distance) zone in which there is a large movement in a time axis (distance axis) direction. Thus, the position identification unit 243 determines a position at which an abnormality has newly occurred based on the GPS data

[0061]

As illustrated in FIG. 13, the position identification unit 243 extracts a section in which the time axis expansion/contraction amount is equal to or greater than the expansion/contraction amount threshold value (step S301), acquires longitude/latitude information at a moment when the maximum acceleration is generated (step S302), and records the acquired longitude/latitude information in the monitoring result database 265 as the position information of a peak value, for example. However, the identified position information may be output in any manner. In FIG. 13, the processing in steps S101 to S103 and the processing in steps S201 to S212 are identical to those in FIG. 8.

[0062]

According to the third embodiment, measurement values can be appropriately monitored in a manner similar to the first and the second embodiments, and when a time axis expansion/contraction amount is equal to or greater than an expansion/contraction amount threshold value, it is possible to identify position information in which the state is considered to have been largely changed, for example, by combining the GPS data.

[0063]

Note that the third embodiment can be combined with the second embodiment.

[0064]

The embodiments according to the present disclosure have been described in detail with reference to the drawings. However, the specific configuration of the present disclosure is not limited to these embodiments. Design change without departing from the gist of the present disclosure or the like is also included. For example, both of the determination of an expansion/contraction amount and the determination of a correlation coefficient in the first and the second embodiments may be performed, and when either one or both are satisfied, the evaluation based on a non-linearly expanded/contracted measured acceleration waveform (step S205) may be performed. In addition, monitoring and evaluation of a measured acceleration waveform may be performed for each section during operation, or may be collectively performed at the end of operation every day, for example. The non-linear expansion/contraction unit 241 may non-linearly expand or contract a reference waveform based on a distance between each measurement value of a measured waveform (measured acceleration waveform) and each reference measurement value of the reference waveform (reference acceleration waveform).

[0065]

Computer Configuration

FIG. 17 is a schematic block diagram illustrating a configuration of a computer according to at least one embodiment.

A computer 90 includes a processor 91, a main memory 92, a storage 93, and an interface 94.

The above-described acceleration monitoring devices 2 and 2a are implemented in the computer 90. Operations of each of the processing units described above are held in the form of programs in the storage 93. The processor 91 reads a program from the storage 93 to deploy the program in the main memory 92, and performs the processing in accordance with the program. Furthermore, the processor 91 allocates, in the main memory 92, a storage area corresponding to each of the storage units described above in accordance with the program.

[0066]

The program may be a program for achieving part of the functions that the computer 90 implements. For example, the program may be a program that achieves a function by combining with another program that has been stored in

the storage or combining with another program installed on another device. Note that, in other embodiments, the computer may include a custom large scale integrated circuit (LSI) such as a programmable logic device (PLD), in addition to or in place of the configuration described above. Examples of the PLD include a programmable array logic (PAL), a generic array logic (GAL), a complex programmable logic device (CPLD), and a field programmable gate array (FPGA). In this case, some or all of the functions implemented by the processor may be implemented by the integrated circuit.

[0067]

Other examples of the storage 93 include a hard disk drive (HDD), a solid state drive (SSD), a magnetic disk, a magneto-optical disk, a compact disc read only memory (CD-ROM), a digital versatile disc read only memory (DVD-ROM), and a semiconductor memory. The storage 93 may be an internal medium directly connected to a bus of the computer 90, or may be an external medium connected to the computer 90 through the interface 94 or a communication line. In addition, in a case where this program is distributed to the computer 90 through a communication line, the computer 90 that receives the distribution may develop this program on the main memory 92 to perform the processing. In at least one of the embodiments, the storage 93 is a non-temporary tangible storage medium.

[0068]

Notes

The acceleration monitoring devices 2 and 2a according to each of the embodiments can be understood as follows, for example.

[0069]

(1) The acceleration monitoring devices 2 and 2a according to a first aspect include the non-linear expansion/contraction unit 241 configured to non-linearly expand or contract a measured waveform (measured acceleration waveform) based on distances between respective measurement values of the measured waveform and respective reference measurement values of a reference waveform (reference acceleration waveform), and the determination unit 242 configured to determine whether or not there is an abnormality in the measured waveform based on a predetermined value (time axis expansion/contraction amount, correlation coefficient) obtained by non-linearly expanding or contracting the measured waveform. According to this aspect and the respective aspects below, measurement values can be appropriately monitored.

[0070]

(2) The acceleration monitoring devices 2 and 2a according to a second aspect are the acceleration monitoring devices 2 and 2a according to (1) above, wherein the predetermined value is an expansion/contraction amount (time axis expansion/contraction amount) of each of the measurement values of the measured waveform having been non-linearly expanded or contracted, and the determination unit 242 determines that there is an abnormality in the measured waveform when the expansion/contraction amount is equal to or greater than a predetermined expansion/contraction amount threshold value (step S204).

[0071]

(3) The acceleration monitoring device 2a according to a third aspect is the acceleration monitoring device 2a according to (2) above, further including the position identification unit 243, wherein position information is associated with at least part of the measurement values of the measured waveform, and the position identification unit 243 identifies a position corresponding to any of the measurement values that has the expansion/contraction amount equal to or greater than the expansion/contraction amount threshold value by using the position information.

[0072]

(4) The acceleration monitoring device 2a according to a fourth aspect is the acceleration monitoring device 2a according to (3) above, wherein the position identification unit 243 identifies a position corresponding to a measurement value having a peak value among the measurement values having the expansion/contraction amount equal to or greater than the expansion/contraction amount threshold value.

[0073]

(5) The acceleration monitoring devices 2 and a 2a according to a fifth aspect are the acceleration monitoring devices 2 and the 2a according to (1) above, wherein the predetermined value is a correlation coefficient between the measured waveform having been non-linearly expanded or contracted and the reference waveform, and the determination unit 242 determines that there is an abnormality in the measured waveform when the correlation coefficient is equal to or less than a predetermined correlation coefficient threshold value.

[0074]

(6) The acceleration monitoring devices 2 and a 2a according to a fifth aspect are the acceleration monitoring devices 2 and 2a according to (1) to (5), wherein the measured waveform and the reference waveform are acceleration waveforms measured in the vehicle 3 traveling on the track T1.

Reference Signs List

[0075]

1 Automated guideway transit

2, 2a Acceleration monitoring device

3, 3a, 3b, 3c Vehicle

23 Acquisition unit

24, 24a Monitoring unit

241 Non-linear expansion/contraction unit

242 Determination unit

243 Position identification unit

26 Storage unit

32 Accelerometer

33 Position identification information acquisition device

301 Vehicle body

303 Bogie

304 Shock absorber

Claims

[Claim 1]

A monitoring device comprising:

a non-linear expansion/contraction unit configured to non-linearly expand or contract a measured waveform based on distances between respective measurement values of the measured waveform and respective reference measurement values of a reference waveform; and

a determination unit configured to determine whether or not there is an abnormality in the measured waveform based on a predetermined value obtained by non-linearly expanding or contracting the measured waveform.

[Claim 2]

The monitoring device according to claim 1 wherein

the predetermined value is an expansion/contraction amount of each of the measurement values of the measured waveform having been non-linearly expanded or contracted, and

the determination unit determines that there is an abnormality in the measured waveform when the expansion/contraction amount is equal to or greater than a predetermined expansion/contraction amount threshold value.

[Claim 3]

The monitoring device according to claim 2, further comprising a position identification unit, wherein

position information is associated with at least part of the measurement values of the measured waveform, and

the position identification unit identifies a position corresponding to any of the measurement values that has the expansion/contraction amount equal to or greater than the expansion/contraction amount threshold value by using the position information.

[Claim 4]

The monitoring device according to claim 3, wherein the position identification unit identifies a position corresponding to a measurement value having a peak value among the measurement values having the expansion/contraction amount equal to or greater than the expansion/contraction amount threshold value.

[Claim 5]

The monitoring device according to claim 1, wherein

the predetermined value is a correlation coefficient between the measured waveform having been non-linearly expanded or contracted and the reference waveform, and

the determination unit determines that there is an abnormality in the measured waveform when the correlation coefficient is equal to or less than a predetermined correlation coefficient threshold value.

[Claim 6]

The monitoring device according to any one of claims 1 to 5, wherein the measured waveform and the reference waveform are acceleration waveforms measured in a vehicle traveling on a track.

[Claim 7]

A monitoring method comprising:

non-linearly expanding or contracting a measured waveform based on distances between respective measurement values of the measured waveform and respective reference measurement values of a reference waveform; and

determining whether or not there is an abnormality in the measured waveform based on a predetermined value obtained by non-linearly expanding or contracting the measured waveform.

[Claim 8]

A program for causing a computer to execute:

non-linearly expanding or contracting a measured waveform based on distances between respective measurement values of the measured waveform and respective reference measurement values of a reference waveform; and

determining whether or not there is an abnormality in the measured waveform based on a predetermined value obtained by non-linearly expanding or contracting the measured waveform.