

Description

Title of Invention

DETECTION DEVICE, DETECTION METHOD,
DETECTION PROGRAM, AND DETECTION SYSTEM

5

Technical Field

[0001]

The present invention relates to, for example, a
detection device that detects the occurrence of bridging in
10 a hopper.

Background Art

[0002]

In a general waste incineration plant, a funnel-
15 shaped device called a hopper is provided. Waste stored in
a waste storage facility called "waste pit" is grabbed and
lifted up by, for example, a crane and introduced into the
hopper. Then, the waste is fed to an incinerator and
incinerated. In such a waste incineration plant, the waste
20 introduced into the hopper may form a bridge-shaped
blockage in the hopper. This phenomenon is called
bridging.

[0003]

When bridging occurs, waste above a bridge
25 continues to stay at the same position. As a result, the

height (level) of waste stored in the hopper is kept high. In general, introduction of waste into the hopper is triggered by descending of the level of waste. Accordingly, when bridging occurs, no waste is newly introduced into the hopper. Meanwhile, waste below the bridge is fed to the incinerator and sequentially incinerated. Accordingly, in a case where the bridge is left as is, an amount of waste in the incinerator may decrease. In a case where the bridge is further left alone, waste in the incinerator may decrease and waste to be incinerated may be absent in the incinerator.

[0004]

In a case where the amount of waste decreases or the waste becomes absent, a temperature inside the incinerator may decrease and heating by a burner or the like may become necessary. Further, in some cases, the incinerator needs to be stopped. For example, Patent Literature 1 discloses a technology for avoiding such a situation. Patent Literature 1 discloses detection of bridging on the basis of a hopper level which is periodically measured.

Citation List

[Patent Literature]

[0005]

[Patent Literature 1]

Japanese Patent Application Publication, *Tokukaihei*,
No. 10-238735

Summary of Invention

5 Technical Problem

[0006]

However, waste contains various objects and therefore does not have a definite shape. Further, part of the waste may be spattered and/or may be caught on an
10 upper portion of the hopper when the waste is introduced into the hopper. Accordingly, it is difficult to stably and accurately measure the hopper level. Therefore, in a case where bridging is to be detected on the basis of the hopper level, it is inevitable to set a detection threshold with
15 which false detection does not occur frequently. In some cases, this has caused a significant time lag between the occurrence of bridging and detection of the bridging. Note that such a problem is not limited to a hopper that is installed in a waste incinerator, but occurs commonly in
20 hoppers for any purposes in which bridging may occur.

[0007]

An aspect of the present invention is attained in view of the above problem. An object of an aspect of the present invention is to provide a detection device and the like
25 capable of quickly detecting the occurrence of bridging.

Solution to Problem

[0008]

In order to solve the above problem, a detection device in accordance with an aspect of the present invention includes: a movement data generation section
5 configured to generate movement data from a plurality of time-series images each obtained by capturing, from above, an image of a hopper in which an object is accommodated, the movement data indicating a movement state of the
10 object in a period in which the plurality of images were captured; and a detection section configured to detect occurrence of bridging in the hopper, on the basis of the movement data which has been generated by the movement data generation section.

15 [0009]

Further, in order to solve the above problem, a detection method in accordance with an aspect of the present invention is a method for detecting bridging, the method being executed by one or more information
20 processing devices, the method including the steps of: generating movement data from a plurality of time-series images each obtained by capturing, from above, an image of a hopper in which an object is accommodated, the movement data indicating a movement state of the object
25 in a period in which the plurality of images were captured;

and detecting occurrence of bridging in the hopper, on the basis of the movement data which has been generated in the step of generating the movement data.

[0010]

5 Further, in order to solve the above problem, a detection device in accordance with an aspect of the present invention includes: a movement data generation section configured to generate movement data from a plurality of time-series images each obtained by capturing,
10 from above, an image of a hopper in which an object is accommodated, the movement data indicating a movement state of the object in a period in which the plurality of images were captured; and a detection section configured to detect occurrence of bridging in the hopper, on the basis
15 of an output value obtained by inputting the movement data to a trained model which has learned a relation between a movement state of the object and the presence or absence of the occurrence of bridging at the time when the object is in the movement state.

20 [0011]

 Further, in order to solve the above problem, a detection system in accordance with an aspect of the present invention includes: an imaging device configured to capture, from above, an image of a hopper in which an
25 object is accommodated; a detection device configured to

detect occurrence of bridging in the hopper, on the basis
of movement data which has been generated from a
plurality of time-series images captured by the imaging
device and which indicates a movement state of the object
5 in a period in which the plurality of images were captured;
and a notification device configured to provide a
notification as to the occurrence of bridging when the
detection device detects the occurrence of bridging.

Advantageous Effects of Invention

10 [0012]

An aspect of the present invention makes it possible
to quickly detect the occurrence of bridging.

Brief Description of Drawings

15 [0013]

Fig. 1 is a block diagram illustrating an example of
a configuration of a main part of a detection device in
accordance with Embodiment 1 of the present invention.

Fig. 2 is a diagram illustrating an example of a
20 configuration of a detection system in accordance with
Embodiment 1 of the present invention.

Fig. 3 is a diagram illustrating an example of a
method of determining the presence or absence of waste.

Fig. 4 is a diagram illustrating an example of a
25 method of generating movement data.

Fig. 5 is a diagram illustrating a method of detecting the occurrence of bridging.

Fig. 6 is a flowchart illustrating an example of a process executed by the detection device.

5 Fig. 7 is a block diagram illustrating an example of a configuration of a main part of a detection device in accordance with Embodiment 2 of the present invention.

Description of Embodiments

10 [0014]

Embodiment 1

(System configuration)

15 The following description will discuss a configuration of a detection system 100 in accordance with the present embodiment, with reference to Fig. 2. Fig. 2 is a diagram illustrating an example of a configuration of the detection system 100. Fig. 2 illustrates an example in which the detection system 100 is applied to detection of bridging in a hopper A that is provided in a waste incineration plant. Note that the detection system 100 is applicable to not only the hopper A but also a hopper for any purpose in which bridging may occur. Although an object accommodated in the hopper A is waste G, the detection system 100 can detect bridging in a hopper in which any object other than the waste G is accommodated.

20

25

[0015]

In the waste incineration plant illustrated in Fig. 2, a waste pit B for storing the waste G and an incinerator C for incinerating the waste G are provided. The waste G in the waste pit B is introduced into the hopper A with use of a crane. An inclined surface A1 which is inclined so as to stretch outward is formed at an upper portion of the hopper A. The waste G slides over the inclined surface A1 and enters the inside of the hopper A, and is temporarily accommodated in the hopper A. Then, the waste G in the hopper A is sequentially fed into the incinerator C through an opening A2 at a lower part of the hopper A and incinerated. Note that in the example of Fig. 2, the vicinity of the opening A2 is a cavity where there is no waste G. This is because the waste G forms a bridge-shaped blockage in the hopper A, that is, bridging occurs. In a normal operation state in which no bridging occurs, the waste G is also present in the vicinity of the opening A2.

[0016]

The detection system 100 is a system which, as described above, detects the occurrence of bridging in the hopper A, and includes a detection device 1, an imaging device 2, and a notification device 3. The imaging device 2 is provided above the hopper A, and captures images of the hopper A from above at predetermined time intervals. In

addition, the detection device 1 obtains images captured by the imaging device 2, and detects the occurrence of bridging in the hopper A with use of the images. When the detection device 1 detects the occurrence of bridging, the notification device 3 notifies a user who uses the detection system 100 of the occurrence of bridging.

[0017]

Note that although Fig. 2 shows an example in which a notification on the occurrence of bridging is given by a sound, that is, an example in which the notification device 3 is a sound output device, an embodiment of the present invention is not limited to this example. The notification method can be any method that allows a notification target person to recognize that bridging occurs. Any device in accordance with that notification method can be applied to the notification device 3. The notification device 3 can be, for example, an alarm lamp or a display device.

[0018]

More specifically, the imaging device 2 captures a plurality of time-series images of the hopper A. Then, the detection device 1 detects the occurrence of bridging in the hopper A on basis of movement data which is generated from the plurality of time-series images captured by the imaging device 2 and which indicates a movement state of

the waste G in a period in which the plurality of images were captured.

[0019]

5 Note that the inventors of the present invention have found, by scrutinizing images obtained by capturing, from above, images of various types of hoppers, that an image captured at the time when bridging occurs exhibits a different characteristic from an image captured at the time when no bridging occurs. More specifically, the inventors
10 of the present invention have found that there is a difference in movement state of an object which is captured in images between the time when bridging occurs and the time when an operation is normally performed.

[0020]

15 The detection device 1 detects the occurrence of bridging on the basis of this finding. As described above, there is a difference in movement state of the waste G captured in images between the time when the bridging occurs and the time when an operation is normally
20 performed. Therefore, it is possible to detect the occurrence of bridging on the basis of movement data which has been generated from a plurality of time-series images and which indicates a movement state of the waste G in a period in which the plurality of images were

captured. Note that such a detection method will be discussed later in detail.

[0021]

Further, since a movement state specific to the time
5 when bridging occurs is observed in an image immediately
after the bridging occurs, the above configuration makes
it possible to quickly detect the occurrence of bridging.
Furthermore, according to the above configuration, stable
and accurate detection can be carried out, as compared
10 with bridging detection on the basis of a hopper level. The
reason for this is as follows: although it is difficult to
stably and accurately measure the height of an indefinite-
shape object with use of a hopper level meter, the
movement state specific to the time when bridging occurs
15 can be stably observed in images obtained by capturing an
image of the hopper A from above.

[0022]

As described above, the detection system 100
includes the detection device 1, the imaging device 2, and
20 the notification device 3. The imaging device 2 captures,
from above, images of the hopper A in which the waste G
is accommodated. The detection device 1 detects the
occurrence of bridging in the hopper A on basis of the
movement data which is generated from a plurality of time-
25 series images captured by the imaging device 2 and which

indicates a movement state of the waste G in a period in which the plurality of images were captured. The notification device 3 provides a notification on the occurrence of bridging when the detection device 1 detects the occurrence of bridging. With this configuration, it is possible to quickly detect the occurrence of bridging and provide a notification on the occurrence of bridging.

[0023]

The location of the detection device 1 is not limited to any particular location. For example, the detection device 1 can be disposed in a waste incineration plant or can be disposed in a monitoring center or the like in which monitoring of a plurality of waste incineration plants is carried out. Further, although Fig. 2 illustrates an example in which the occurrence of bridging in one hopper A is monitored and detected by one detection device 1, it is also possible to monitor and detect, with use of one detection device 1, the occurrence of bridging in a plurality of hoppers. In this case, for example, the detection device 1 can be a cloud server.

[0024]

Further, a process to be carried out at the time when the occurrence of bridging is detected is not limited to the example described above. For example, in a case where a bridge elimination device for eliminating bridging is

provided in a waste incineration plant, the detection device 1 may be configured to cause the bridge elimination device to operate at the time when the occurrence of bridging is detected and to automatically eliminate the bridging. The bridging elimination device can be any device capable of eliminating bridging. For example, the bridging elimination device can be a device including a pushing body for pushing waste that clogs the hopper.

[0025]

(Configuration of detection device)

The following description will discuss a configuration of the detection device 1 with reference to Fig. 1. Fig. 1 is a block diagram illustrating an example of a configuration of a main part of the detection device 1. As illustrated in Fig. 1, the detection device 1 includes: a control section 10 which performs overall control of sections of the detection device 1; and a storage section 11 in which various data used by the detection device 1 are stored. The detection device 1 further includes: a communication section 12 for allowing the detection device 1 to communicate with another device; an input section 13 for receiving input of various data to the detection device 1; and an output section 14 for allowing the detection device 1 to output various data.

[0026]

Further, the control section 10 includes a data obtaining section 101, a determination section 102, a movement data generation section 103, a detection section 104, and a notification control section 105. Meanwhile, the storage section 11 stores an image DB 111.

[0027]

The data obtaining section 101 obtains a plurality of time-series images which have been obtained by capturing an image of the hopper A from above. As described above, in the detection system 100, the capturing device 2 captures, from above, the plurality of time-series images of the hopper A. Therefore, the data obtaining section 101 can obtain the images captured by the imaging device 2. Note that the data obtaining section 101 may obtain the images from the imaging device 2 through communication via the communication section 12 or may obtain the images inputted via the input section 13. The data obtaining section 101 stores, in the image DB 111, the images obtained. Note that the imaging device 2 may capture a moving image. In this case, the data obtaining section 101 can obtain the plurality of time-series images (e.g., frame images captured at predetermined intervals) from the moving image captured by the imaging device 2.

[0028]

The determination section 102 determines whether or not an image of waste is captured in a target area that is to be analyzed for detecting the presence or absence of the occurrence of bridging in the images which have been
5 obtained by the data obtaining section 101. A method of determining the waste in the target region will be described later in detail, with reference to Fig. 3.

[0029]

The movement data generation section 103 generates
10 movement data from the plurality of time-series images which have been obtained by the data obtaining section 101 and which have been recorded in the image DB 111. The movement data indicates a movement state of the waste in a period in which the plurality of images were
15 captured. The method of generating the movement data will be described later in detail with reference to Fig. 4.

[0030]

The detection section 104 detects the occurrence of bridging in the hopper A, on the basis of the movement
20 data which has been generated by the movement data generation section 103. The method of detecting the occurrence of bridging will be described later in detail with reference to Fig. 5.

[0031]

The notification control section 105 provides a notification on the occurrence of bridging when the detection section 104 detects the occurrence of bridging. Specifically, the notification control section 105 causes the notification device 3 to output a sound indicating the occurrence of bridging when the detection section 104 detects the occurrence of bridging. The notification control section 105 thus provides a notification on the occurrence of bridging. Note that the method of providing a notification on the occurrence of bridging is not particularly limited, provided that the method can allow a notification target person to recognize that bridging occurs. For example, in a case where the detection device 1 is disposed near the notification target person, the notification control section 105 can cause the output section 14 to output information indicating that bridging occurs. For example, the notification control section 105 can provide the notification by, for example, transmitting a message to a terminal device which is possessed by the notification target person.

[0032]

As described above, the detection device 1 includes the movement data generation section 103 and the detection section 104. The movement data generation section 103 generates movement data from a plurality of

time-series images each obtained by capturing an image of the hopper A from above. The movement data indicates a movement state of waste in a period in which the plurality of images were captured. The detection section 104 detects the occurrence of bridging in the hopper A, on the basis of the movement data generated by the movement data generation section 103. With this configuration, it is possible to quickly detect the occurrence of bridging.

[0033]

Further, the movement data can be generated, provided that there are two images captured at different times. This will be described in detail later. Therefore, without need to carry out machine learning or the like, it is possible to immediately start operating the detection device 1 in a waste incineration plant. Further, even in a case where an installation location and an imaging angle of the imaging device 2 are slightly changed, it is possible to carry out detection without any particular influence on the detection. Furthermore, it is also assumed that dirt adheres to a lens of the imaging device 2 installed in the waste incineration plant. However, since there is no movement in the dirt that has adhered, influence of such dirt on generation of the movement data is also limited. That is, the detection system 100 including the detection

device 1 has an advantage in that the detection system 100 can be easily introduced and be stably operated.

[0034]

(Determination of presence or absence of waste)

5 The following description will discuss determination of the presence or absence of waste by the determination section 102, with reference to Fig. 3. Fig. 3 is a diagram illustrating an example of a method of determining the presence or absence of waste. The image D illustrated in
10 Fig. 3 is an image obtained by capturing an image of the hopper from above. In the image D, an image of waste sliding down an inclined surface of the hopper is captured. However, the waste all over the inclined surface is not captured. Specifically, an image of the waste is captured
15 in a downstream region d2 of the inclined surface of the hopper. However, no image of the waste is captured in an upstream region d1 of the hopper.

[0035]

 Assume here that the movement data generation
20 section 103 has generated movement data for a region, like the region d1, in which no image of waste is captured. Then, the movement amount indicated by the movement data may be zero or a value close to zero. When the movement amount reaches zero or a value close to zero,
25 the occurrence of bridging may be falsely detected

although in reality, there is no waste and no bridging occurs.

[0036]

In order to avoid such false detection as described
5 above, the detection device 1 includes the determination
section 102. The determination section 102 determines
whether or not waste is captured in the target region in
the image. The movement data generation section 103 then
10 generates movement data indicating the movement amount
between the images for which the determination section
102 has determined that waste is captured in the target
region. This makes it possible to prevent false detection
as described above, since an image in which no target
15 object is captured in the target region is not used for
detection of bridging. Note that it is preferable that the
target region be set on the inclined surface of the hopper,
and more specifically, on a downstream portion, like the
region d2, on the inclined surface.

[0037]

20 Whether or not waste is captured may be determined
with use of captured images or alternatively, may be
determined after predetermined image processing is
carried out on the captured images so as to facilitate
determination of the presence or absence of waste.
25 Examples of the image processing include the Canny

method. The Canny method is an algorithm for edge detection in images. An image D1 illustrated in Fig. 3 is an image that has been generated from the image D as a result of edge detection by the Canny method. In general, appearance of waste is much more complicated than the surface shape of the hopper. Therefore, in an example of Fig. 3, a large number of edges are detected in the region d2 in which waste is captured as compared with the region d1 in which no waste is captured.

[0038]

Therefore, the determination section 102 may (a) apply the Canny method to the image in which the hopper is captured, so as to detect edges; (b) then, determine, as an image in which waste is captured, an image in which the number of edges detected in the target region is more than or equal to a threshold value; and (c) determine, as an image in which no waste is captured, an image in which the number of edges detected in the target region is less than the threshold value.

[0039]

Of course, an edge detection technique other than the Canny method can be applied. It is also possible to determine the presence or absence of waste by a technique other than the edge detection. For example, the determination section 102 may determine the presence or

absence of waste by analyzing luminance values and/or RGB values of respective pixels constituting the image. Further, for example, the determination section 102 can determine the presence or absence of waste by a trained
5 model (e.g., neural network model) which has been trained so as to be capable of determining the presence or absence of waste.

[0040]

(Method of generating movement data)

10 The following description will discuss a method of generating movement data by the movement data generation section 103 with reference to Fig. 4. Fig. 4 is a diagram illustrating an example of the method of generating movement data. More specifically, Fig. 4
15 illustrates an example in which movement data F is generated by the image correlation method. The movement data F indicates a movement state of waste between an image E1, which has been obtained by capturing an inclined surface of a hopper at time t , and an image E2,
20 which has been obtained by capturing the inclined surface of the hopper at time $t + \Delta t$. Note that in Fig. 4, y direction is a direction in which the waste descends, that is, a direction from an upstream side to a downstream side of the inclined surface of the hopper (see the inclined surface

A1 of Fig. 2). On the other hand, x direction is a direction perpendicular to the y direction on the inclined surface.

[0041]

The image correlation method is a method in which,
5 for two images in a time series, an amount of movement of
each of particles captured in the images is calculated by
image processing, and the movement amount thus
calculated is expressed as a vector. For example, in the
image E1, waste indicated in a broken-line box is captured
10 at a position e1. However, in the image E2, the waste is
captured at a position e2 that is a position lower than the
position e1. The movement state of the waste is expressed
as a vector f1 which indicates a displacement from the
position e1 to the position e2 in the movement data F. In
15 addition, vectors are similarly calculated for other
positions.

[0042]

In this manner, the movement data F shows the
movement state of the waste at each of the positions in the
20 images E1 and E2. Specifically, the movement data F
indicates that the waste at each of the positions in the
images E1 and E2 is moving in the y direction (toward a
downstream side, i.e., the descending direction of the
inclined surface of the hopper). Note that in the movement
25 data F, vectors whose values of y-direction components are

more than the threshold value are indicated by solid arrows, and vectors whose values of y-direction components are less than the threshold value are indicated by broken arrows. This also shows that there are positions where movement of the waste is fast and positions where movement of the waste is slow.

[0043]

As described above, the movement data generation section 103 can generate movement data indicating movement amounts by which respective image elements have moved, in the descending direction, between the images E1 and E2. The respective image elements are captured at a plurality of predetermined positions that are set on the inclined surface captured in the images E1 and E2.

[0044]

On the inclined surface of the hopper, the waste slides down in substantially same descending directions. Therefore, the inclined surface of the hopper is a position suitable for determining whether descending of the waste is smooth or disrupted. Therefore, with the above configuration, it is possible to generate movement data accurately indicating whether descending of the waste is smooth or disrupted. Then, by detecting the occurrence of

bridging with use of this movement data, it is possible to carry out highly reliable detection.

[0045]

Note that it is possible to generate, together with the
5 above movement data, movement data for an image portion
in which an image other than the inclined surface is
captured. In this case, the detection section 104 may
detect bridging with use of the movement data of the target
region that is set in a portion where the inclined surface
10 is captured, in the movement data that have been
generated by the movement data generation section 103.

[0046]

Of course, a region other than the inclined surface
can be used as the target region since it is only necessary
15 to set, as the target region, a region where the waste moves
substantially in the same direction. For example, of an
inner surface of the hopper, it is possible to set, as the
target region, a region (that, in general, stretches in the
vertical direction) which is on the inner surface and which
20 is connected to the inclined surface at a downstream side
of the inclined surface, or alternatively a region including
both of the inclined surface and a portion other than the
inclined surface.

[0047]

Further, the movement data can be any data that indicates the movement state of the waste, and is not limited to the example described above. For example, a movement rate of the waste can be used as the movement data. Alternatively, a difference image that indicates a difference between two images which have been captured at different times can be used as the movement data.

[0048]

(Method of detecting occurrence of bridging)

The following description will discuss a method of detecting the occurrence of bridging by the detection section 104 with reference to Fig. 5. Fig. 5 is a diagram illustrating a method of detecting the occurrence of bridging. More specifically, Fig. 5 illustrates an example in which the occurrence of bridging is detected with use of movement data H which has been generated from a plurality of time-series images each obtained by capturing an image of the hopper from above. Note that the movement data H is data which is generated by using the image correlation method described above and which indicates movement vectors of respective image elements that are captured at a plurality of predetermined positions set in the images each obtained by capturing an image of the hopper. Further, in Fig. 5, in the movement data H, a box h1 indicates a target region that is to be analyzed for

detecting the presence or absence of the occurrence of bridging.

[0049]

5 An image J shown in Fig. 5 is an enlarged view of the target region in the image of the hopper. In this image J, respective positions at which movement vectors are calculated are plotted. For example, at position j1, a movement vector is calculated to be (-1, 3). As shown in Fig. 5, the positions at which the movement vectors are
10 calculated are uniformly set all over the image J. More specifically, a plurality of positions are arranged in a row in a direction perpendicular to the descending direction of the waste, that is, in the x direction of Fig. 5. At the same
15 time, a plurality of the rows are arranged in the descending direction of the waste, that is, in the y direction of Fig. 5.

[0050]

20 In determining whether or not bridging occurs, first, the detection section 104 determines whether or not a movement amount of the waste is within a normal range for each of the plurality of positions aligned in a row in the x direction.

[0051]

25 For example, on the assumption that a value y of a movement vector, i.e., a movement amount in the

descending direction of the waste, is D , the normal range of D can be defined as $D \geq m1$. $m1$ is the lower limit of the normal range. Note that depending on a position, the movement amount D may be a negative value. This indicates that at that position, the waste is moving in a direction opposite to the descending direction. Such a movement does not normally occur. Accordingly, for such a position where the movement amount D is a negative value, a determination result can be "indeterminable".

[0052]

For example, the detection section 104 can evaluate each position in three levels by the following conditional expressions (1) to (3):

$D \geq m1$ (1)

$m1 > D > 0$ (2)

$D \leq 0$ (3)

It can be said that a position which satisfies the condition of the conditional expression (1) is in a normal movement state in which the waste is smoothly descending.

On the other hand, it can be said that a position which satisfies the condition of the conditional expression (2) is in an abnormal state in which the movement amount of the waste is small and which is specific to a case where bridging occurs. Therefore, for example, the detection section 104 may set an evaluation value to 1 (a value

indicating absence of abnormality) for the position at which the condition of the above conditional expression (1) is satisfied, while setting the evaluation value to 0 (a value indicating presence of abnormality) for the position at which the condition of the above conditional expression (2) is satisfied. For the position at which the condition of the conditional expression (3) is satisfied, the detection section 104 may set the evaluation value to -1 (a value indicating "indeterminable").

[0053]

For example, if $m1 = 1$, the value y of the movement vector is 3 at the position $j1$ in the image J of Fig. 5. The position $j1$ thus satisfies the condition of the above conditional expression (1). Therefore, in this case, the evaluation value of the position $j1$ is 1. Evaluation values are similarly calculated for other positions.

[0054]

Next, on the basis of a determination result as to whether or not the movement amount for each position is within the normal range, the detection section 104 determines whether or not the waste is normally moving for each of the rows each including the positions aligned in the x direction. For example, in a case where the detection section 104 calculates evaluation values of 1, 0, or -1 for each position as described above, the detection

section 104 can evaluate each of the rows in three levels by using the conditional expressions (4) to (6) below. Note that Sum(D) is the sum of the evaluation values of the movement amounts at the positions aligned in the row in the x direction.

Sum(D) > 0 (4)

Sum(D) = 0 (5)

Sum(D) < 0 (6)

It can be said that a row which satisfies the condition of the conditional expression (4) is in a normal movement state in which overall, the waste is smoothly descending. On the other hand, it can be said that a row which satisfies the condition of the conditional expression (5) is in an abnormal movement state in which overall, the movement amount of the waste is small and which is specific to a case where bridging occurs. Therefore, the detection section 104 can set the evaluation value to 1 for the row which satisfies the condition of the above conditional expression (4) and set the evaluation value to 0 for the row which satisfies the condition of the above conditional expression (5). Further, for a row which satisfies the condition of the above conditional expression (6), the detection section 104 may set the evaluation value to -1.

[0055]

For example, a row K1 in the image J of Fig. 5 includes five positions in total, including the position j1. Therefore, for the row K1, the sum of evaluation values of respective movement amounts calculated for these five positions is calculated as Sum(D). On the basis of the Sum(D) thus calculated, the evaluation value for the row K1 is calculated by the conditional expressions (4) to (6). Further, evaluation values are similarly calculated for other rows. In Fig. 5, the evaluation values of respective rows are indicated in a column L. In this example, each of the evaluation values of all of the rows is 1, that is, the evaluation values indicate "normal".

[0056]

Finally, the detection section 104 generates an overall determination result on the basis of respective determination results for the rows described above and detects the occurrence of bridging on the basis of this overall determination result. For example, on the assumption that the respective evaluation values of the rows calculated as described above are each assumed to be J and the sum of the evaluation values of all of the rows is Sum (J), the detection section 104 can generate an overall determination result by the conditional expressions (7) to (9) below and detect the occurrence of

bridging on the basis of the overall determination result.
Note that $m2$ is a predetermined threshold value.

$$\text{Sum}(J) \geq m2 \quad (7)$$

$$\text{Sum}(J) < m2 \quad (8)$$

5 $-1 \in J \quad (9)$

10 In a case where the condition of the conditional
expression (7) is satisfied, it can be said that an overall
movement state is a normal movement state in which the
waste is smoothly descending. Therefore, the detection
section 104 determines that the overall determination
result is 1 and that no bridging occurs. In contrast, in a
case where the condition of the conditional expression (8)
is satisfied, it can be said that an overall movement state
is an abnormal movement state in which the movement
15 amount of the waste is small and which is specific to a
case where bridging occurs. Therefore, the detection
section 104 determines that the overall determination
result is 0 and that bridging occurs. Note that a case where
the condition of the above conditional expression (9) is
20 satisfied corresponds to a case where a determination
result is "indeterminable" for one or more rows. In this
case, the detection section 104 may set the overall
determination result to -1 and determines that the
presence or absence of the occurrence of bridging is
25 "indeterminable".

[0057]

As described above, the detection section 104 can (i) determine whether or not the movement amount is within the normal range for each of the plurality of positions aligned in a row in the x direction; (ii) determine whether or not the waste in the row is normally moving on the basis of determination result in the foregoing (i); and (iii) detect the occurrence of bridging on the basis of the determination result in the foregoing (ii).

[0058]

In general, waste is composed of a plurality of objects. Therefore, constituent elements of the waste, which are located at positions aligned in a row in the direction perpendicular to the descending direction, slide down on the hopper while roughly maintaining the row. Accordingly, it is effective to detect, along the row in the direction perpendicular to the descending direction, the movement state specific to the time when bridging occurs. However, variation may exist in movement amounts of the constituent elements of the waste depending on positions on the hopper. Therefore, for example, even in a case where the waste is smoothly descending as a whole, it is assumed that the movement amounts at some of the positions are outside the normal range.

[0059]

In light of the above, according to the above configuration, the following configuration is employed: on the basis of a determination result as to whether or not the movement amount at each of the positions aligned in a row is within the normal range, whether or not the waste in the row is normally moving is determined. This makes it possible to appropriately determine whether or not the waste is normally moving and to accurately detect the occurrence of bridging on the basis of such a determination result, even in a case where variation exists in the movement amounts at the positions aligned in the x direction.

[0060]

In addition, as described above, the detection section 104 may determine the foregoing (i) and (ii) for each of the plurality of rows, and detect the occurrence of bridging in the hopper on the basis of the determination results for each of the rows. According to this configuration, the occurrence of bridging is detected on the basis of the determination result as to whether or not the waste in each of the rows is normally moving. Therefore, even in a case where variation occurs in the determination results in each of the rows, it is possible to accurately detect the occurrence of bridging.

[0061]

Note that the above determination method is merely an example, and various techniques can be applied as the method of detecting the occurrence of bridging on the basis of the movement data. For example, the detection section 104 may: identify movement amounts at respective positions in the target region from the movement data; then compare, with a predetermined threshold value, the sum or average value of the movement amounts thus identified; and in a case where the sum or average value is greater than or equal to the threshold value, the determination result may be "normal", whereas in a case where the sum or average value is less than the threshold value, the determination result may be "abnormal", that is, it may be determined that bridging occurs.

[0062]

Further, for example, the detection section 104 may detect the occurrence of bridging with use of only the movement data at positions (e.g., positions included in the row K1 of Fig. 5) aligned in a row in the x direction. In this case, for example, the detection section 104 may detect the occurrence of bridging from the evaluation results based on the above conditional expressions (4) to (6).

[0063]

Furthermore, various thresholds which are to be used for detection of the occurrence of bridging and which

include the above-described threshold $m1$ may be each a fixed value or a variation value. For example, in a case where a rate at which waste is fed from the hopper to the incinerator (waste feeding rate) is high, the movement rate of the waste in an upper portion of the hopper also increases. Therefore, the threshold $m1$ may be changed in conjunction with the waste feeding rate. Specifically, for a higher feeding rate, the threshold $m1$ can be set to be larger. This makes it possible to detect that bridging occurs, in a case where the movement of the waste in the upper portion of the hopper is slow although the waste feeding rate is high.

[0064]

(Flow of process)

A flow of the process (detection method) executed by the detection device 1 will be described with reference to Fig. 6. Fig. 6 is a flowchart illustrating an example of a process executed by the detection device 1. Note that the process of Fig. 6 is carried out, for example, each time the imaging device 2 captures a new image.

[0065]

In S1, the data obtaining section 101 obtains time-series images each obtained by capturing, from above, an image of the hopper and stores the time-series images in the image DB 111. As described above, since these images

are captured by the imaging device 2 (see Fig. 2), the data obtaining section 101 can obtain the images captured by the imaging device 2.

[0066]

5 In S2, the determination section 102 determines whether or not waste is captured in the target region in the image obtained in S1. Since how to determine whether or not the waste is captured in the target region is as described above with reference to Fig. 3, the description
10 will not be repeated here. In a case where the determination result is YES in S2, the process proceeds to S3, whereas in a case where the determination result is NO in S2, the process shown in Fig. 6 ends.

[0067]

15 In S3 (movement data generation step), the movement data generation section 103 generates movement data from the following images: an image obtained in S1; and an image captured earlier than the image obtained in S1. The movement data indicates the
20 movement state of the waste in a period in which the images were captured. For example, in a case where an image captured at time $t + \Delta t$ is obtained in S1, the movement data generation section 103 reads out an image captured at time t from the image DB 111. The movement
25 data generation section 103 then generates the movement

data that indicates the movement state of the waste in a period from time t to time $t + \Delta t$. Since the method of generating the movement data has been described above with reference to Fig. 4, the description will not be repeated here.

[0068]

In S4, with use of the movement data generated in S3, the detection section 104 determines whether or not the movement amount is within the normal range for each of positions in the target region that have been set in the image obtained in S1. In S5 that follows S4, the detection section 104 determines, on the basis of the determination results in S4, whether or not the movement states in respective rows, in each of which the positions are aligned in the direction (x direction in Fig. 5) perpendicular to the descending direction of the waste, are normal. Then, in S6, the detection section 104 generates an overall determination result on the basis of the determination results of the respective rows in S5. Since the determination methods in S4 to S6 have been described with reference to Fig. 5, the detailed description will not be repeated here.

[0069]

In S7 (detection step), the detection section 104 detects the occurrence of bridging on the basis of the

overall determination result in S6. For example, in a case where the overall determination result is expressed in any one of numerical values of 1 (normal), 0 (abnormal) and - 1 (indeterminable), the detection section 104 determines that bridging does not occur (NO in S7) if the overall determination result in S6 is 1. In this case, the process of Fig. 6 then ends. If the overall determination result of S6 is 0, however, the detection section 104 determines that bridging occurs (YES in S7). That is, in this case, the detection section 104 detects the occurrence of bridging. After this, the process proceeds to S8.

[0070]

Note that processing in the case of "indeterminable" may be predetermined. For example, if the overall determination result is "indeterminable", the detection section 104 may end the process in Fig. 6 or cause the process to proceed to S8 and provide a user with a notification that the determination result is "indeterminable".

[0071]

In S8, the notification control section 105 provides a notification on the occurrence of bridging. Specifically, the notification control section 105 provides a notification on the occurrence of bridging, by causing the notification device 3 to output a sound that indicates the occurrence

of bridging. Note that in a case where the waste incineration plant is provided with a bridge elimination device for eliminating bridging, the notification control section 105 in S8 may cause the bridging elimination device to operate and eliminate bridging, together with providing the notification or instead of providing the notification,.

[0072]

As described above, the foregoing detection method in accordance with the present embodiment includes the movement data generation step (S3) and the detection step (S7). In the movement data generation step (S3), movement data is generated from a plurality of time-series images each obtained by capturing, from above, an image of a hopper in which waste is accommodated. The movement data indicates a movement state of the waste in a period in which the plurality of images were captured. In the detection step (S7), the occurrence of bridging is detected on the basis of the movement data generated in the movement data generation step (S3). With this detection method, it is possible to quickly detect the occurrence of bridging.

[0073]

Note that as described at the beginning of Embodiment 1, application of the detection system 100 is

not limited to application to a hopper in a waste incineration plant, but it is possible to apply the detection system 100 to hoppers for any use in which bridging may occur. An object to be accommodated in such a hopper is not limited to waste. That is, the "waste" described in the above Embodiment can be read as any "object".

[0074]

Embodiment 2

The following description will discuss another embodiment of the present invention. For convenience of explanation, members which are identical in function to the members described in Embodiment 1 are given respective identical reference signs, and descriptions of those members are not repeated.

[0075]

(Configuration of detection device)

The following description will discuss a configuration of a detection device 1A in accordance with the present embodiment with reference to Fig. 7. Fig. 7 is a block diagram illustrating an example of a configuration of a main part of the detection device 1A. The detection device 1A differs from the detection device 1 illustrated in Fig. 1 in the following points: the detection section 104 is changed to a detection section 104A; and a trained model 112 is stored in the storage section 11.

[0076]

The detection section 104A is configured to detect the occurrence of bridging in the hopper, on the basis of an output value obtained by inputting movement data, which has been generated by a movement data generation section 103, to a trained model 112 which has learned a relation between a movement state of an object and the presence or absence of the occurrence of bridging at the time when the object is in the movement state. Note that the movement data generation section 103 generates the movement data as in Embodiment 1. Further, the object can be waste or can be something other than waste.

[0077]

As described above, the detection device 1A includes the movement data generation section 103 and the detection section 104A. The movement data generation section 103 is configured to generate movement data from a plurality of time-series images each obtained by capturing, from above, an image of a hopper in which an object is accommodated, the movement data indicating a movement state of the object in a period in which the plurality of images were captured. The detection section 104A is configured to detect the occurrence of bridging in the hopper, on the basis of an output value obtained by inputting the movement data to the trained model 112

which has learned a relation between a movement state of an object and the presence or absence of the occurrence of bridging at the time when the object is in the movement state.

5 [0078]

The above configuration, like the detection device 1 of Embodiment 1, is based on a finding that there is a difference in movement amount of an object captured in an image between the time when bridging occurs and the
10 time when an operation is normally performed. As described above, there is a difference in movement state of an object captured in an image between the time when bridging occurs and the time when an operation is normally performed. Therefore, according to the
15 configuration of the detection device 1A, it is possible to detect the occurrence of bridging.

[0079]

Further, since a movement state specific to the time when bridging occurs is observed in an image immediately
20 after the bridging occurs, the above detection device 1A, like the detection device 1 in accordance with Embodiment 1, is capable of quickly detecting the occurrence of bridging. Furthermore, the detection device 1A, like the detection device 1 in accordance with Embodiment 1, can

carry out stable and accurate detection, as compared with bridging detection on the basis of a hopper level.

[0080]

(Trained model)

5 The trained model 112 has been generated by learning the relation between a movement state of an object and the presence or absence of the occurrence of bridging when the object is in the movement state, as described above.

10 [0081]

 In a case where training data to be used for generating the trained model 112 is to be generated, first, the following images are collected: a plurality of time-series images each obtained by capturing, from above, an
15 image of a hopper at the time when bridging occurs; and a plurality of time-series images each obtained by capturing, from above, an image of the hopper which is normally operating.

[0082]

20 Next, movement data is generated from the images that have been collected as described above. Specifically, images from the plurality of images are paired in time series order, and movement data is generated for each pair is generated. This process is carried out for the images
25 captured at the time when bridging occurs and also for the

images captured at the time when an operation is normally performed. This generates movement data at the time when bridging occurs and movement data at the time when an operation is normally performed. Note that the movement data can be any data that indicates a movement state of an object. For example, the movement data may be generated by the image correlation method as in Embodiment 1.

[0083]

Further, the movement data at the time when bridging occurs is associated with correct answer data indicating abnormality, that is, indicating that bridging occurs. The movement data associated with the correct answer data is used as the training data. Further, the movement data at the time when the operation is normally performed are associated with correct answer data indicating normality, that is, correct answer data indicating that no bridging occurs. A resultant data is used as the training data.

[0084]

By carrying out machine learning with use of the training data, the trained model 112 for classifying inputted movement data into movement data at normal times and movement data at abnormal times is generated. Note that an algorithm of the machine learning may be any

algorithm that can generate the trained model 112 capable of classifying inputted movement data into the movement data at normal times and the movement data at abnormal times. For example, a convolutional neural network or the like with high image classification accuracy is suitable, but the present invention is not limited to this example.

[0085]

Note that as the training data of the trained model 112, a feature amount extracted from the movement data can be used. Such a feature amount also indicates the movement amount of the object, and is one kind of the movement data. In addition, data other than the movement data can be included in the training data of the trained model 112. For example, the training data can include: (i) the number of edges calculated by the Canny method from images each obtained by capturing an image of the hopper from above; (ii) RGB values of the images; and/or the like.

[0086]

(Flow of process)

A flow of a process carried out by the detection device 1A is as shown in Fig. 6. However, processing in each of S4 to S6 of Fig. 6 is replaced with processing in which an output value is obtained by inputting movement data into the trained model 112. Further, in S7 (detection

step), the occurrence of bridging is detected on the basis of the output value of the trained model 112.

[0087]

In other words, the foregoing detection method in accordance with the present embodiment includes a movement data generation step and a detection step. In the movement data generation step, movement data is generated from a plurality of time-series images each obtained by capturing, from above, an image of a hopper in which an object is accommodated, the movement data indicating a movement state of the object in a period in which the plurality of images were captured. In the detection step, the occurrence of bridging in the hopper is detected, on the basis of an output value obtained by inputting the movement data to the trained model 112 which has learned a relation between a movement state of an object and the presence or absence of the occurrence of bridging at the time when the object is in the movement state. With this detection method, it is possible to quickly detect the occurrence of bridging.

[0088]

[Variations]

A subject that executes each process described in the above embodiments can be any subject, and is not limited to the example described above. That is, a device(s)

constituting the detection system 100 can be changed as appropriate, provided that the processes described in the above embodiments can be executed.

[0089]

5 For example, although the detection system 100 of Fig. 1 includes the detection device 1 and the notification device 3 as separate devices, the detection device 1 can be configured to include the notification device 3. Conversely, the function of the detection device 1 can be distributed
10 to a plurality of information processing devices (computers). For example, it is possible to (i) cause an information processing device in the cloud to generate movement data, (ii) transmit the movement data to an information processing device provided in a waste
15 incineration plant, and (iii) cause the information processing device located in the waste incineration plant to detect bridging.

[0090]

[Software Implementation Example]

20 Functions of the detection devices 1 and 1A (hereinafter, referred to as "device") can be realized by a program (detection program) for causing a computer to function as the device, the program being for causing the computer to function as control blocks (in particular,
25 sections provided in the control section 10) of the device.

[0091]

In this case, the device includes, as hardware for executing the above program, a computer that has at least one control device (e.g., processor) and at least one storage
5 device (e.g., memory). The foregoing functions described in the above embodiments are realized by executing the program by the control device and the storage device.

[0092]

The program can be stored in one or more non-
10 transitory computer-readable storage medium. The storage medium may or may not be provided in the device. In the latter case, the program may be made available to the device via any wired or wireless transmission medium.

[0093]

15 Further, some or all of functions of the control blocks can be realized by a logic circuit. For example, an embodiment of the present invention encompasses, in its scope, an integrated circuit in which a logic circuit that functions as the foregoing control blocks is formed. In
20 addition, it is possible to realize the functions of the blocks by, for example, a quantum computer.

[0094]

The present invention is not limited to the embodiments, but can be altered by a skilled person in the
25 art within the scope of the claims. The present invention

also encompasses, in its technical scope, any embodiment derived by combining technical means disclosed in differing embodiments.

5	Reference Signs List
	[0095]
	100 detection system
	1 detection device
	102 determination section
10	103 movement data generation section
	104 detection section
	2 imaging device
	3 notification device
	1A detection device
15	104A detection section

Claims

[Claim 1]

A detection device comprising:

5 a movement data generation section configured to
generate movement data from a plurality of time-series
images each obtained by capturing, from above, an image
of a hopper in which an object is accommodated, the
movement data indicating a movement state of the object
in a period in which the plurality of images were captured;
10 and

a detection section configured to detect occurrence
of bridging in the hopper, on the basis of the movement
data which has been generated by the movement data
generation section.

[Claim 2]

15 The detection device according to claim 1, wherein
the movement data generation section generates the
movement data indicating movement amounts of movement
20 of image elements in a descending direction between the
images, the respective image elements being captured at
respective predetermined positions that are set on an
inclined surface of the hopper captured in the images.

[Claim 3]

The detection device according to claim 2, wherein the detection section is configured to:

(1) determine whether or not the movement amounts are within a normal range, for the respective positions aligned in a row in a direction perpendicular to the descending direction;

(2) determine whether or not the object in the row is normally moving, on the basis of a determination result in the (1); and

(3) detect the occurrence of bridging in the hopper, on the basis of a determination result in the above (2).

[Claim 4]

The detection device according to claim 3, wherein:

a plurality of the rows each including the positions aligned in the direction perpendicular to the descending direction are provided along the descending direction; and

the detection section is configured to determine the (1) and the (2) for each of the plurality of rows, and detect the occurrence of bridging in the hopper, on the basis of the determination results in the (1) and the (2) for each of the rows.

[Claim 5]

The detection device according to any one of claims 2 to 4, further comprising:

5 a determination section configured to determine whether or not the object is captured in a target area where the positions in the image are set,

 the movement data generation section generating the movement data indicating the movement amounts between
10 the images for each of which the determination section has determined that the object is captured in the target region.

[Claim 6]

A detection device comprising:

15 a movement data generation section configured to generate movement data from a plurality of time-series images each obtained by capturing, from above, an image of a hopper in which an object is accommodated, the movement data indicating a movement state of the object
20 in a period in which the plurality of images were captured;
 and

 a detection section configured to detect occurrence of bridging in the hopper, on the basis of an output value obtained by inputting the movement data to a trained
25 model which has learned a relation between a movement

state of the object and the presence or absence of the occurrence of bridging at the time when the object is in the movement state.

5 [Claim 7]

A method for detecting bridging, the method being executed by one or more information processing devices, the method comprising the steps of:

10 generating movement data from a plurality of time-series images each obtained by capturing, from above, an image of a hopper in which an object is accommodated, the movement data indicating a movement state of the object in a period in which the plurality of images were captured; and

15 detecting occurrence of bridging in the hopper, on the basis of the movement data which has been generated in the step of generating the movement data.

[Claim 8]

20 A detection program for causing a computer to function as a detection device according to claim 1 or 6, the detection program causing the computer to function as the movement data generation section and the detection section.

25

[Claim 9]

A detection system comprising:

an imaging device configured to capture, from above,
5 an image of a hopper in which an object is accommodated;

a detection device configured to detect occurrence of
bridging in the hopper, on the basis of movement data
which has been generated from a plurality of time-series
images captured by the imaging device and which indicates
10 a movement state of the object in a period in which the
plurality of images were captured; and

a notification device configured to provide a
notification as to the occurrence of bridging when the
detection device detects the occurrence of bridging.