

Description

Title of Invention

PREDICTION DEVICE, PREDICTION METHOD,
PREDICTION PROGRAM, FACILITY CONTROL DEVICE,
5 FACILITY CONTROL METHOD, AND CONTROL PROGRAM

Technical Field

[0001]

The present invention relates to, for example, a
prediction device for predicting properties of an
10 incineration target object to be incinerated in an
incinerator.

Background Art

[0002]

15 In a general waste incineration plant, a funnel-
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 in the hopper is fed by a waste
20 feeding device to an incinerator, in the order of
introduction into the hopper, and incinerated. Examples
of a technology related to the hopper is disclosed in, for
example, Patent Literature 1 below. Patent Literature 1
discloses detection of bridging on the basis of a hopper
25 level which is periodically measured.

Citation List

[Patent Literature]

[0003]

[Patent Literature 1]

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

Summary of Invention

Technical Problem

10 [0004]

 The waste introduced into the hopper is sequentially
fed to the incinerator by the waste feeding device and
incinerated, as described above. However, how the waste
burns differs depending on properties of the waste fed into
15 the incinerator. For example, in a case where wet waste
containing a lot of water is fed to the incinerator,
temperature inside the incinerator may decrease. In
contrast, in a case where dry waste easy to burn is fed to
the incinerator, the temperature inside the incinerator
20 may increase. This phenomenon is not limited to cases of
waste incineration, but is common to cases of incineration
of any incineration target object.

[0005]

 Therefore, making it possible to ascertain properties
25 of an incineration target object introduced into the hopper

in a stage prior to incineration is considered to contribute to improvement in operation of an incineration plant. For example, it would be possible to predict a state inside the incinerator from the properties of the incineration target object. This would make it possible to prevent the state from worsening. Further, for example, automatic control of the incinerator and automatic control of introduction of the incineration target object into the hopper would become possible. However, prediction of the properties of the incineration target object introduced into the hopper has not been performed conventionally. For example, Patent Literature 1 above does not even suggest prediction of properties of waste introduced into the hopper.

[0006]

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, for example, a prediction device that contributes to improvement in operation of an incineration plant.

Solution to Problem

[0007]

In order to solve the above problem, a prediction 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, from above,
an image of a hopper in an incineration plant where an
incineration target object introduced into the hopper is fed
to an incinerator at a specified rate, the movement data
5 indicating a movement state of the incineration target
object; and a prediction section configured to predict
properties of the incineration target object to be
incinerated, on the basis of the rate and the movement
data generated by the movement data generation section.

10 [0008]

Further, in order to solve the above problem, a plant
control 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
15 time-series images each obtained by capturing, from above,
an image of a hopper in an incineration plant where an
incineration target object introduced into the hopper is fed
to an incinerator at a specified rate, the movement data
indicating a movement state of the incineration target
20 object; and an equipment control section configured to
carry out control on the basis of the rate and the movement
data generated by the movement data generation section,
the control being at least one selected from the group
consisting of (1) control of introduction of the incineration
25 target object into the hopper; (2) control of the rate; (3)

control of a transfer speed of the incineration target object in the incinerator; (4) control of combustion of the incineration target object in the incinerator; and (5) control of stirring of the incineration target object.

5 [0009]

In order to solve the above problem, a prediction method in accordance with an aspect of the present invention is a method for predicting properties of an incineration target object, the method being executed by one or more information 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 an incineration plant where the incineration target object introduced into the hopper is fed to an incinerator at a specified rate, the movement data indicating a movement state of the incineration target object; and predicting the properties of the incineration target object to be incinerated, on the basis of the rate and the movement data generated in the step of generating the movement data.

20 [0010]

In order to solve the above problem, a plant control method in accordance with an aspect of the present invention is a method for controlling a plant, the method being executed by one or more information processing

25

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 an incineration plant where an incineration target object introduced into the hopper is fed to an incinerator at a specified rate, the movement data indicating a movement state of the incineration target object; and carrying out control on the basis of the rate and the movement data generated in the step of generating the movement data, the control being at least one selected from the group consisting of (1) control of introduction of the incineration target object into the hopper; (2) control of the rate; (3) control of a transfer speed of the incineration target object in the incinerator; (4) control of combustion of the incineration target object in the incinerator; and (5) control of stirring of the incineration target object.

Advantageous Effects of Invention

[0011]

An aspect of the present invention can contribute to improvement in operation of an incineration plant.

Brief Description of Drawings

[0012]

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

5 Fig. 2 is a diagram illustrating an example of a configuration of a plant control system including the prediction device.

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

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

Fig. 5 is a diagram showing a relation between a waste feeding rate and a movement amount.

Fig. 6 is a flowchart showing an example of a process executed by the prediction device.

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

Fig. 8 is a diagram illustrating a relation between a predicted value and an actual value of bulk density.

20 Fig. 9 is a diagram for illustrating a method of predicting a lower calorific value.

Fig. 10 is a flowchart showing an example of a process executed by the prediction device.

Fig. 11 is a block diagram illustrating an example of main components of a plant control device in accordance with Embodiment 3 of the present invention.

Fig. 12 is a flowchart showing an example of a process executed by the plant control device.

Description of Embodiments

[0013]

Embodiment 1

(System configuration)

The following description will discuss a configuration of a plant control 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 plant control system 100. Fig. 2 illustrates an example in which the plant control system 100 is applied to a waste incineration plant. Note that the plant control system 100 is applicable to any incineration plant where any incineration target object, which is not limited to waste, is incinerated.

[0014]

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
5 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.

[0015]

10 The plant control system 100 is a system which predicts properties of waste to be incinerated in the incinerator C, and includes a prediction device 1 and an imaging device 2. The imaging device 2 is provided above the hopper A, and captures images of the hopper A from
15 above at predetermined time intervals. Then, the prediction device 1 obtains the images captured by the imaging device 2, and predicts, with use of the images, the properties of the waste to be incinerated.

[0016]

20 More specifically, the imaging device 2 captures a plurality of time-series images of the hopper A. Then, the prediction device 1 predicts the properties of the waste, on basis of movement data which is generated from the plurality of time-series images captured by the imaging
25 device 2 and which indicates a movement state of the waste

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

[0017]

5 The inventors of the present invention have found,
as a result of scrutinizing images each obtained by
capturing an image of the hopper from above, that a
difference in properties between incineration target
objects appears as a difference in movement state between
the incineration target objects. For example, the inventors
10 have found that even in a case where respective rates at
which the incineration target objects are fed to the
incinerator are set to be the same, an incineration target
object which has a high moisture content and which is
thus difficult to incinerate tends to have a larger
15 movement amount per unit time in the hopper than an
incineration target object which has a low moisture
content and which is thus easy to burn.

[0018]

20 The prediction device 1 predicts the properties of the
waste on the basis of this finding. That is, a difference in
properties of waste appears as a difference in movement
state of the waste captured in images. Therefore, according
to the above configuration, it is possible to predict the
properties of the waste. Then, ascertaining the properties
25 of the waste is useful for proper operation of an

incineration plant, so that the prediction device 1 can contribute to improvement in operation of the incineration plant.

[0019]

5 Specifically, the prediction device 1 controls equipment in the waste incineration plant, on the basis of a prediction result on the properties of the waste. This makes it possible to carry out appropriate control in accordance with the properties of the waste and therefore
10 to contribute to improvement in operation of the incineration plant. Note that control of the equipment in the waste incineration plant can be performed by an operator or the like of the waste incineration plant. In this case, the prediction device 1 may output, to the operator
15 or the like, the prediction result of the properties of the waste. In this case, the prediction device 1 does not need to control the equipment.

[0020]

 A location where the prediction device 1 is disposed
20 is not limited to any particular location. For example, the prediction 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
25 an example in which the properties of waste in one waste

incineration plant are predicted by one prediction device 1, it is also possible to predict the properties of waste in a plurality of waste incineration plants with use of one prediction device 1. In this case, for example, the
5 prediction device 1 may be a cloud server.

[0021]

(Configuration of prediction device)

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

[0022]

Further, the control section 10 includes a data obtaining section 101, a determination section 102, a
25 movement data generation section 103, a standard

movement amount calculation section 104, a property prediction section (prediction section) 105, an influence prediction section 106, and an equipment control section 107. Further, in the storage section 11, an image DB 111 and a standard movement amount calculation formula 112 are stored.

[0023]

The data obtaining section 101 obtains a plurality of time-series images each by capturing an image of the hopper A from above. As described above, in the plant control 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.

[0024]

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

[0025]

The movement data generation section 103 generates 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 captured. The method of generating the movement data will be described later in detail with reference to Fig. 4.

[0026]

The standard movement amount calculation section 104 determines a rate at which the waste is fed to the incinerator, that is, a waste feeding rate. Then, the standard movement amount calculation section 104 calculates, with use of the standard movement amount calculation formula 112 from the waste feeding rate thus determined, a standard waste movement amount (hereinafter, referred to as "standard movement amount")

for when the waste is fed to the incinerator at the waste feeding rate specified above.

[0027]

The standard movement amount calculation formula 112 is a mathematical expression that indicates a relation between the waste feeding rate and the standard movement amount of the waste at the time when the waste is fed to the incinerator at the waste feeding rate. The standard movement amount calculation formula 112 and a method of calculating the standard movement amount with use of the standard movement amount calculation formula 112 will be described later in detail with reference to Fig. 5.

[0028]

The property prediction section 105 predicts the properties of the waste to be incinerated, on the basis of the movement data generated by the movement data generation section 103 and the waste feeding rate. Specifically, the property prediction section 105 calculates, as a prediction result of the properties of the waste, a difference between (a) a movement amount which is indicated by the movement data generated by the movement data generation section 103 and (b) the standard movement amount which is calculated by the standard movement amount calculation section 104.

[0029]

The influence prediction section 106 predicts an influence of incineration of the waste on a combustion state of the incinerator, on the basis of the properties of the waste predicted by the property prediction section 105.

5 The prediction result outputted by the influence prediction section 106 can indicate the magnitude of the influence on the combustion state. For example, in a case where the magnitude of the influence on the combustion state is expressed in four levels including "large", "medium",
10 "small", and "no influence", the influence prediction section 106 may output information indicating any one of the levels as the prediction result. Alternatively, the influence prediction section 106 may output, as the prediction result, a predicted value of the combustion state (e.g., a predicted value of a lower calorific value).
15 Such prediction of the influence on the combustion state will be described later with reference to Fig. 5.

[0030]

20 The equipment control section 107 controls the equipment in the waste incineration plant, on the basis of the prediction result of the influence prediction section 106. For example, the equipment control section 107 can carry out at least control that is one selected from the group consisting of the following (1) to (4): (1) control of
25 introduction of the waste into the hopper; (2) control of

the waste feeding rate; (3) control of a transfer speed (grate speed) of the waste in the incinerator; and (4) control of combustion of the waste in the incinerator.

[0031]

5 Note that regarding the above control (1), (i) in a case where it is desired to promote combustion, part that is relatively easy to burn among the waste in the waste pit is introduced into the hopper, whereas (ii) in a case where it is desired to suppress combustion, part that is relatively
10 difficult to burn among the waste is introduced into the hopper. A property distribution of the waste in the waste pit may be separately managed or may be determined on the basis of a prediction result of the property prediction section 105 as described later.

15 [0032]

 Further, regarding the above (2), (i) in a case where it is desired to promote combustion, the waste feeding rate can be increased, whereas (ii) in a case where it is desired to suppress combustion, the waste feeding rate can be
20 decreased. The same applies to the grate speed in the above (3). Note that in some circumstances, it may be effective to decrease the waste feeding rate and/or decrease the grate speed, as control for promoting combustion.

25 [0033]

Further, regarding the above (4), control of combustion of the waste can be realized by, for example, heating with a burner or control of a supply amount of combustion air. That is, in a case where it is desired to promote combustion (i.e., in a case where it is desired to increase the amount of heat generated), heating by a burner or increasing the supply amount of combustion air can be carried out. Conversely, in a case where it is desired to suppress combustion (i.e., in a case where it is desired to decrease the amount of heat generated), the amount of combustion air supplied can be reduced. Note that in some circumstances, it may be effective to reduce the supply amount of combustion air as control for suppressing combustion.

[0034]

Further, waste whose image is captured at the time when an image of the hopper is captured from above is waste that has been existed in the waste pit until immediately before the image of the waste is captured. It is possible to determine from which position in the waste pit the waste is obtained. Therefore, it is possible to predict a property distribution of the waste in the waste pit from the prediction result of the property prediction section 105 or from the prediction result of the influence prediction section 106.

[0035]

The equipment control section 107 may carry out control of stirring of the waste in the waste pit on the basis of this property distribution. For example, the equipment control section 107 may control to preferentially carry out stirring in an area in which waste difficult to burn is distributed. Alternatively, the equipment control section 107 can mix and stir the waste in an area where waste difficult to burn is distributed and the waste in an area where waste easy to burn is distributed, so as to homogenize the waste. Note that stirring of the waste is a process for improving the properties (particularly, combustibility) of the waste. Stirring of the waste is carried out, for example, by grabbing and lifting up the waste with use of a crane and dropping the waste, or by scattering the waste which has been grabbed and lifted up.

[0036]

As described above, the prediction device 1 includes the movement data generation section 103 and the property prediction section 105. The movement data generation section 103 generates movement data, which indicates a movement state of waste, from a plurality of time-series images each obtained by capturing, from above, an image of a hopper in an incineration plant where the waste introduced into the hopper is fed to an incinerator

at a specified waste feeding rate. The property prediction section 105 predicts the properties of the waste on the basis of the movement data generated and the waste feeding rate.

5 [0037]

As described above, the difference in properties of waste appears as the difference in movement state of the waste captured in the images. Therefore, according to the above configuration, it is possible to predict the properties
10 of the waste. Further, ascertaining the properties of the waste is useful for proper operation of the incineration plant, so that the above configuration can contribute to improvement in operation of the incineration plant.

[0038]

15 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 prediction
20 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 predict the properties of the waste without any particular influence on prediction. Furthermore, it is also
25 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 plant control system 100
5 including the prediction device 1 has an advantage in that
the plant control system 100 can be easily introduced and
be stably operated.

[0039]

(Determination of presence or absence of waste)

10 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
15 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
20 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.

[0040]

Assume here that the movement data generation
25 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, a false prediction result with regard to waste that does not actually exist may be outputted.

[0041]

In order to avoid such false prediction as described above, the prediction 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 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 the false prediction as described above, since an image in which no target object is captured in the target region is not used for prediction of the properties of the waste. 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.

[0042]

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. 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.

[0043]

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.

[0044]

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 model (e.g., neural network model) which has been trained so as to be capable of determining the presence or absence of waste.

[0045]

(Method of generating movement data)

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 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,

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.

[0046]

The image correlation method is a method in which, 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 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 addition, vectors are similarly calculated for other positions.

[0047]

In this manner, the movement data F shows the movement state of the waste at each of the positions in the 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 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.

[0048]

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.

[0049]

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 predicting the properties of the waste with use of this movement data, it is possible to carry out highly reliable prediction. This is because, as described above, the difference in properties of waste appears as the difference in movement state of the waste captured in the images.

[0050]

Note that it is possible to generate, together with the above movement data, movement data for an image portion in which an image other than the inclined surface is captured. In this case, the property prediction section 105 may predict the properties of the waste with use of the movement data of the target region that is set in a portion where the inclined surface is captured, in the movement data that have been generated by the movement data generation section 103.

[0051]

Of course, a region other than the inclined surface can be used as the target region since it is only necessary to set, as the target region, a region where the waste moves substantially in the same directions. 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 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.

[0052]

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.

[0053]

(Calculation of standard movement amount to prediction of combustion state)

The following description will discuss a method of calculating a standard movement amount by the standard movement amount calculation section 104, a method of predicting properties of waste by the property prediction section 105, and a method of predicting a combustion state by the influence prediction section 106, with reference to Fig. 5. Fig. 5 is a diagram showing a relation between the waste feeding rate and the movement amount.

[0054]

On a graph H shown in Fig. 5, movement amounts of waste of various properties measured at various waste feeding rates in a waste incineration plant are plotted. Note that a histogram h1 indicating a distribution of the waste feeding rate is shown on an upper side of the graph H, and a histogram h2 indicating a distribution of the movement amount is shown on a right side of the graph H. Note here that the movement amount is a movement amount in a descending direction of the waste captured between two time-series images each obtained by capturing an image of the waste.

[0055]

As illustrated in Fig. 5, there is a correlation between the waste feeding rate and the movement amount of the waste. According to the correlation, as the waste feeding rate increases, the movement amount increases. This correlation can be formulated, for example, by regression analysis. In an example of Fig. 5, a line indicating $y = F(x)$, which is a regression equation that is obtained by regression analysis and that indicates a relation between the waste feeding rate and the movement amount of the waste, is indicated by h3. That is, h3 is a regression line. The prediction device 1 stores, in the

storage section 11, such a regression equation as the standard movement amount calculation formula 112.

[0056]

The standard movement amount calculation section 5 104 calculates a standard movement amount at the current waste feeding rate, by determining the current waste feeding rate and substituting a result of this determination into the standard movement amount calculation formula 112. This makes it possible to 10 calculate a standard movement amount of a reasonable value. For example, in a case where the current waste feeding rate is x_1 , the standard movement amount is $y = F(x_1)$.

[0057]

15 In this case, the property prediction section 105 can calculate, as a prediction result, the difference between the movement amount which is indicated by the movement data generated by the movement data generation section 103 and the standard movement amount of the waste. As 20 described above, a result of study by the inventors of the present invention shows the following: waste that has a high moisture content and that is difficult to burn tends to have a larger movement amount per unit time in the hopper than waste that has a low water content and that 25 is easy to burn. Therefore, it can be said that the

difference between the movement amount indicated by the movement data and the standard movement amount indicates the combustibility of the waste. Therefore, with the above configuration, it is possible to calculate, as the prediction result, a value indicating the combustibility of the waste.

[0058]

For example, assume that in a case where the current waste feeding rate is x_1 , the movement amount indicated by the movement data generated by the movement data generation section 103 is y_1 as in the example of Fig. 5. In Fig. 5, such a combination of the waste feeding rate and the movement amount is represented by a point h_4 on the graph plane of the graph H. As described above, the standard movement amount at the time when the waste feeding rate is x_1 is $y = F(x_1)$. Therefore, in this example, the property prediction section 105 calculates, as the prediction result, $y' = y_1 - F(x_1)$.

[0059]

A larger value of y' thus calculated indicates more deviation of the properties of the waste from those of a standard waste. More specifically, in a case where y' is a negative value, a larger absolute value of y' indicates a smaller movement amount of the waste. In general, light waste has a small movement rate as compared with waste

having a standard weight, and has a low moisture content and is thus easy to burn. Accordingly, it can be said that waste whose y' is a negative value and whose absolute value of y' is large is easy to burn.

5 [0060]

In contrast, in a case where y' is a positive value, a larger the absolute value of y' indicates a larger movement amount of the waste. In general, heavy waste has a large movement rate as compared with waste having a standard weight, and has a high moisture content and is thus difficult to burn. Accordingly, it can be said that waste whose y' is a positive value and whose absolute value of y' is large is difficult to burn.

[0061]

15 Therefore, for example, in Fig. 5, in a case where the movement amount and the waste feeding rate of a certain waste are plotted in a region $h5$ that is set above the regression line $h3$, it can be said that the waste is difficult to burn. In contrast, in Fig. 5, in a case where the movement amount and the waste feeding rate of a certain waste are plotted in a region $h6$ that is set below the regression line $h3$, it can be said that the waste is easy to burn. Since the point $h4$ is within the region $h6$ below the regression line $h3$, it can be said that the waste at the point $h4$ is easy to burn.

[0062]

In view of the above, the influence prediction section 106 may classify waste according to the value of y' and output a classification result as the prediction result. For example, the influence prediction section 106 may predict that there is an influence on the combustion state in a case where the value of y' calculated by the property prediction section 105 is plotted in the region h5 or h6. The influence prediction section 106 can determine the magnitude of the influence in accordance with the magnitude of the value of y' . On the other hand, the influence prediction section 106 may predict that there is no influence on the combustion state when the value of y' is plotted in a region between the regions h5 and h6.

[0063]

Note that the method of predicting the combustion state is not limited to the example described above. As the method, a technique that corresponds to the combustion state to be predicted may be used as appropriate. For example, the influence prediction section 106 may predict a lower calorific value. In this case, it is sufficient to formulate a correlation between the value of y' and the lower calorific value. Then, the influence prediction section 106 can predict the lower calorific value by using a formula obtained by such formulation.

[0064]

Further, a method of obtaining a standard movement amount is not limited to the example described above. For example, as in the example described above, after the movement amount of waste of various properties is measured at various waste feeding rates in a waste incineration plant, the waste feeding rates may be divided into respective sections corresponding to a plurality of numerical ranges and the standard movement amount in each of the sections may be preliminarily obtained. The standard movement amount may be, for example, an average value or a median value of the movement amounts in each of the sections. In this case, the standard movement amount calculation section 104 can determine the standard movement amount on the basis of which category the current waste feeding rate belongs to.

[0065]

Further, instead of determining the standard movement amount by a linear model as in regression analysis, the standard movement amount can be obtained by, for example, a non-linear model such as a neural network. In this case, a machine-trained standard movement amount prediction model that has learned the relation between the waste feeding rate and the standard movement amount is prepared in advance. Then, the

standard movement amount calculation section 104 can calculate the standard movement amount by inputting the waste feeding rate to this standard movement amount prediction model.

5 [0066]

(Flow of process)

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

[0067]

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.

[0068]

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 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.

[0069]

In S3 (the step of generating movement data), 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 movement state of the waste that is an incineration target object. 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 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.

[0070]

In S4, the standard movement amount calculation section 104 determines the waste feeding rate and calculates, with use of the standard movement amount

calculation formula 112, the standard movement amount from the waste feeding rate thus determined. Note that the value to which the waste feeding rate is set may be inputted by a user of the prediction device 1 via the input section 13 or, alternatively, may be determined by communicating with a control device of a waste incineration plant via the communication section 12.

[0071]

In S5 (the step of predicting properties), the property prediction section 105 predicts the properties of the waste to be incinerated. More specifically, the property prediction section 105 calculates, as a prediction result, the difference between (a) the movement amount which is indicated by the movement data generated by the movement data generation section 103 in S3 and (b) the standard movement amount which is calculated with use of the waste feeding rate by the standard movement amount calculation section 104 in S4. As described above, since the standard movement amount is calculated with use of the waste feeding rate, it can be said that in S5, the property prediction section 105 predicts the properties of the waste on the basis of the movement data and the waste feeding rate.

[0072]

In S6, the influence prediction section 106 predicts an influence on a combustion state of the incinerator due to incineration of waste, on the basis of the properties of the waste which have been predicted by the property prediction section 105 in S5. Note that prediction of the combustion state is not essential, and it is also possible to carry out the processing in S7 and subsequent steps on the basis of the prediction result in S5.

[0073]

In S7, the equipment control section 107 determines, on the basis of the prediction result in S6, whether or not to carry out control for keeping the combustion state in the incinerator in a good state. In a case where a determination result is YES in S7, the process proceeds to S8, and in S8, the equipment control section 107 carries out the control for keeping the combustion state in the incinerator in a good state. In contrast, in a case where the determination result is NO in S7, the process in Fig. 6 ends without carrying out processing in S8.

[0074]

Note that it is possible to predetermine a determination criteria for S7 and also to predetermine a method of determining control content in S8. For example, in a case where the magnitude of the influence on the combustion state is predicted in four levels including

"large", "medium", "small", and "no influence", the control can be carried out (the determination result in S7 is YES) in a case where the prediction result is a prediction result other than no influence. Further, the equipment control

5 section 107 may increase an amount of control for promoting or suppressing combustion as a predicted influence on the combustion increases.

[0075]

Note that the equipment control section 107 can

10 determine whether to carry out control to promote combustion or control to suppress combustion, for example, as follows. First, the equipment control section 107 determines that: whether or not the movement amount which is indicated by the movement data generated by the

15 movement data generation section 103 in S3 is larger than the standard movement amount which is calculated with use of the waste feeding rate by the standard movement amount calculation section 104 in S4. In a case where, in this determination, it is determined that the movement

20 amount indicated by the movement data generated by the movement data generation section 103 is larger, the waste is considered to have a higher moisture content and thus be more difficult to burn than standard waste. Therefore, the equipment control section 107 may determine to carry

25 out control to promote combustion (e.g., control to heat by

a burner or to increase the amount of combustion air). In contrast, in a case where it is determined that the standard movement amount is larger, the waste is considered to have a lower moisture content and thus be easier to burn than the standard waste. Therefore, the equipment control section 107 may determine to carry out control to suppress combustion (e.g., control to decrease the amount of combustion air). This makes it possible to keep the combustion state in the incinerator in a good state.

[0076]

Further, in S7, it is possible to carry out control in consideration of a time lag from when the waste is introduced into the hopper until when the waste is fed to the incinerator. For example, the equipment control section 107 may calculate, with use of, for example, the waste feeding rate, a time from when the waste is introduced into the hopper until when the waste is fed to the incinerator. Then, when the time has elapsed, the equipment control section 107 may carry out control in accordance with the influence, which has been predicted, on the combustion state of the waste.

[0077]

Further, depending on the control content, there may be a time lag until the result of the control is reflected on

the combustion state. Therefore, the equipment control section 107 may carry out control so that the result of the control is reflected on the combustion state at the same as or before the waste is fed to the incinerator.

5 [0078]

Further, in S7, the equipment control section 107 may be configured to determine the control content from the prediction result of the property prediction section 105. In this case, processing of S6 is omitted, and the influence prediction section 106 becomes unnecessary.

10 [0079]

As described above, the prediction method in accordance with the present embodiment includes steps (S3) and (S5). In the step (S3), in an incineration plant in which waste introduced into a hopper is fed to an incinerator at a specified waste feeding rate, movement data, which indicates a movement state of the waste, is generated from a plurality of time-series images each obtained by capturing, from above, an image of the hopper. In the step (S5), the properties of the waste to be incinerated are predicted on the basis of the movement data generated in the step (S3) and the waste feeding rate. With this prediction method, it is possible to contribute to improvement in operation of the incineration plant.

25 [0080]

Note that as described at the beginning of Embodiment 1, application of the plant control system 100 is not limited to application to a waste incineration plant, but can be application to any incineration plant for
5 incinerating any incineration target object. Further, the incineration target object accommodated in the hopper is not limited to waste. That is, the "waste" described in the above-described embodiment can be read as any "incineration target object". This also applies to
10 Embodiment 2 and a subsequent embodiment described below.

[0081]

Embodiment 2

The following description will discuss another
15 embodiment of the present invention. For convenience, members which are identical in function to the members described in the above embodiment are given respective identical reference signs, and descriptions of those members are not repeated. This also applies to
20 Embodiment 3 described later.

[0082]

(Configuration of prediction device)

Fig. 7 is a block diagram illustrating an example of a configuration of a main part of a prediction device 1A in
25 accordance with the present embodiment. The prediction

device 1A is different from the prediction device 1 illustrated in Fig. 1 in that: the prediction device 1A does not include a standard movement amount calculation section 104; and the prediction device 1A includes a bulk density prediction section (prediction section) 105A and a calorific value prediction section 106A, instead of the property prediction section 105 and the influence prediction section 106. The prediction device 1A is different from the prediction device 1 also in that: a storage section 11 of the prediction device 1A does not store the standard movement amount calculation formula 112, but instead, stores a bulk density prediction formula 112A and a calorific value prediction formula 113A.

[0083]

The bulk density prediction section 105A calculates a bulk density with use of a movement amount which is indicated by movement data generated by a movement data generation section 103, a waste feeding rate, and the bulk density prediction formula 112A. The bulk density prediction formula 112A is a mathematical expression indicating a relation between (a) the movement amount of the waste and the waste feeding rate and (b) a bulk density of waste. A method of predicting the bulk density will be discussed later in detail with reference to Fig. 8.

[0084]

The calorific value prediction section 106A calculates a predicted value of a lower calorific value (calorific value) at the time when the waste is incinerated, with use of the calorific value prediction formula 113A which indicates a relation between the bulk density of the waste and the lower calorific value (calorific value) at the time when the waste is incinerated. A method of predicting the lower calorific value (calorific value) will be discussed later in detail with reference to Fig. 9.

[0085]

(Method of predicting bulk density)

The inventors of the present invention have studied whether or not it is possible to express the bulk density with use of the movement amount of waste and the waste feeding rate. As a result of such studies, the inventors of the present invention have found the following: it is possible to predict, for waste with various bulk densities, the bulk density by the following mathematical expression (1), which has been obtained by multiple regression analysis using results of measuring the movement amount and the waste feeding rate.

$$y = ax_1 + bx_2 + cx_1 \cdot x_2 + d \quad (1)$$

Note that in the above mathematical expression (1), y represents bulk density [t/m³] (t is a unit of mass: ton), x₁ represents waste feeding rate [m/h], X₂ represents a

movement amount of waste (a non-dimensional amount calculated by the image correlation method), and a to d are coefficients obtained by the multiple regression analysis.

5 [0086]

Fig. 8 is a diagram that shows a relation between a predicted value and an actual value of the bulk density. In Fig. 8, the vertical axis represents the predicted value of the bulk density calculated by the above mathematical expression (1), and the horizontal axis represents the actual bulk density. From a graph J shown in Fig. 8, it can be seen that the bulk density can be accurately predicted by the above mathematical expression (1). In an example shown in the graph J, the coefficient of determination was

10

15 0.8565.

[0087]

Note that the inventors of the present invention also tried to predict the bulk density by the following mathematical expression (2) for comparison.

20 $y = ax_1 + b$ (2)

The predicted value of the bulk density by the mathematical expression (2) also conformed to the actual bulk density to a certain extent, but the coefficient of determination was inferior to that in a case with use of the mathematical expression (1). This shows that the

25

movement amount of the waste contributes to improvement in estimation accuracy of the bulk density.

[0088]

Of course, other than using the mathematical expression (1), various methods can be used to calculate the predicted value of the bulk density from the waste feeding rate and the movement amount. That is, the predicted value of the bulk density can be calculated by using any prediction model which is obtained by modelling the relation between (a) the waste feeding rate and the movement amount of the waste and (b) the bulk density.

[0089]

As described above, the results of studies by the inventors of the present invention show that there is a correlation between (a) the movement amount of waste in a hopper and the waste feeding rate and (b) the bulk density of the waste. Therefore, with use of the prediction device 1A provided with the bulk density prediction section 105A configured to calculate the bulk density with use of the bulk density prediction formula 112A which indicates the relation between (a) the movement amount of the waste and the waste feeding rate and (b) the bulk density of the waste, it is possible to calculate, as the prediction result, a bulk density of a reasonable value.

[0090]

Further, the waste feeding rate is a value which varies per second, and is a highly real-time value. Further, the movement amount of the waste is also highly real-time information that can be obtained, for example, in units of minutes. As will be described below, the movement amount of the waste is also a value that is dependent on the bulk density.

[0091]

First, it has been found that there is a correlation between the waste feeding rate and the movement amount of waste. However, even at one waste feeding rate, the movement amount of the waste varies. One possible cause of this variation is a difference in weight of the waste. That is, it is considered that when the waste settles in the hopper, heavy waste has a greater degree of compression due to its own weight than that of light waste, and thus, the movement amount per unit time of the heavy waste becomes large, that is, a movement rate per unit time of the heavy waste is large. In this way, the rate at which the waste settles in the hopper is affected by compression due to the waste feeding rate and the weight of the waste itself. Therefore, the bulk density, which is the weight per unit volume, varies depending on the waste feeding rate and the degree of compression caused by the weight of the waste itself. Therefore, it can be said that the movement

amount of the waste also depends on the bulk density in addition to the waste feeding rate.

[0092]

As described above, with the above configuration, it is possible to estimate the bulk density of waste in the hopper from the highly real-time information. Specifically, it is possible to calculate the predicted value of the bulk density simply by capturing, from above, an image of the hopper a plurality of times and determining the waste feeding rate at the time of capturing the image of the hopper. This makes it possible to estimate, in real time, the lower calorific value of the waste from the bulk density, and therefore makes it possible to utilize such an estimation result in control of an incinerator.

[0093]

Note that the bulk density can be calculated by the mathematical expression (3) described later. Note however that, in this method, it is necessary to set the predetermined period to a relatively long period such as one day in order to obtain a reasonable value of the waste processing amount (weight). Therefore, the bulk density cannot be calculated at a time that allows the bulk density to be used for control of the incinerator.

[0094]

(Method of predicting lower calorific value)

A method of predicting a lower calorific value by the calorific value prediction section 106A will be described with reference to Fig. 9. Fig. 9 is a diagram showing a method of predicting a lower calorific value. Fig. 9 also shows a schematic cross-sectional view of a lower part of a hopper A illustrated in Fig. 2 in the vicinity of an opening A2.

[0095]

In a waste incineration plant, waste introduced into the hopper stays in the hopper for a while and is then fed to the incinerator so as to be incinerated. Therefore, it is difficult to measure a lower calorific value when waste captured in an image obtained by capturing an image of the hopper from above is incinerated.

[0096]

In light of the above, the inventors of the present invention have first identified a relation between the bulk density and the lower calorific value on the basis of the average calorific value of a day in the incinerator and the average bulk density of that day. The calorific value prediction section 106A obtains the lower calorific value from the bulk density by using the relation thus identified.

[0097]

As illustrated in Fig. 9, the waste accommodated inside the hopper A is fed through the opening A2 into the

incinerator C. Therefore, on the assumption that the cross-sectional area of the opening A2 is S_o and the average waste feeding rate is V , the processing amount of the incinerator C for when the incinerator C is operated for one day (24 hours) is expressed as follows:

[0098]

$$\begin{aligned} & (\text{Daily throughput}) [\text{ton/day}] = \{V [\text{m/h}] \times 24 [\text{h/day}]\} \\ & \times S_o [\text{m}^2] \times (\text{bulk density}) [\text{ton/m}^3] \end{aligned}$$

Therefore, the bulk density is expressed as follows:

[0099]

$$(\text{Bulk density}) = (\text{Daily throughput}) / (V \times 24 \times S_o) \quad (3)$$

K of Fig. 9 is a graph illustrating the relation between the bulk density obtained as described above and the lower calorific value H_u of that day in the incinerator C. As illustrated in Fig. 9, although there is variation, it can be seen that overall, there is a correlation between the bulk density and the lower calorific value. More specifically, the bulk density and the lower calorific value are proportional to each other. Accordingly, the relation between the bulk density and the lower calorific value can be expressed by a straight line k_1 .

[0100]

Therefore, the mathematical expression of the straight line k_1 is stored in the storage section 11 as the calorific value prediction formula 113A. Then, with use of

the mathematical expression, the calorific value prediction section 106A can obtain a lower calorific value from the bulk density predicted by the bulk density prediction section 105A.

5 [0101]

As described above, it has been found that the bulk density of the waste has a correlation with the lower calorific value at the time when the waste is incinerated. Therefore, with the prediction device 1A provided with the calorific value prediction section 106A that predicts the lower calorific value with use of the calorific value prediction formula 113A which indicates the relation between the bulk density and the lower calorific value, it is possible to calculate, as the prediction result, a lower calorific value of a reasonable value.

15 [0102]

Note that as described above, it is possible to calculate the bulk density from the movement amount of the waste and the waste feeding rate. Furthermore, it is possible to calculate the lower calorific value from the bulk density. Therefore, it is also possible to calculate the lower calorific value from the movement amount of the waste and the waste feeding rate without calculating the bulk density. That is, the calorific value prediction section 106A can calculate the lower calorific value of waste by

using a mathematical expression that indicates a relation of: the movement amount indicated by the movement data generated by the movement data generation section 103; the waste feeding rate; and the lower calorific value at the time when the waste to be fed to the incinerator at the waste feeding rate is incinerated. Even in such a configuration, it is possible to calculate, as the prediction result indicating the properties of the waste, a lower calorific value of a reasonable value.

[0103]

As the mathematical expression for calculating the lower calorific value of the waste, for example, a regression expression as described above is applicable. However, the mathematical expression is not limited to this example. The calorific value prediction section 106A can calculate a predicted value of the lower calorific value by using any prediction model which is obtained by modelling the relation between (a) the waste feeding rate and the movement amount of the waste and (b) the lower calorific value.

[0104]

(Flow of process)

A flow of the process (prediction method) executed by the prediction device 1A will be described with reference to Fig. 10. Fig. 10 is a flowchart showing an

example of a process executed by the prediction device 1A. Note that since the description of processing in S11 to S13 of Fig. 10 is identical to that of S1 to S3 of Fig. 6, the description will be omitted.

5 [0105]

In S14 (the step of predicting properties), the bulk density prediction section 105A calculates a predicted value of the bulk density by substituting, into the bulk density prediction formula 112A, the movement amount indicated by the movement data generated in S13 and the waste feeding rate at the time when the waste moves by the movement amount.

[0106]

15 In S15, the calorific value prediction section 106A calculates a predicted value of the lower calorific value by substituting, into the calorific value prediction formula 113A, the predicted value of the bulk density calculated in S14. Note that, as described above, it is also possible to calculate the lower calorific value from the movement amount of the waste and the waste feeding rate without calculating the bulk density. In this case, S14 is omitted, and S15 becomes the step of predicting the properties (specifically, lower calorific value) of the waste.

20

[0107]

In S16, the equipment control section 107 determines, on the basis of the prediction result in S15, whether or not to carry out control for keeping the combustion state in the incinerator in a good state. In a case where a determination result is YES in S16, the process proceeds to S17, and in S17, the equipment control section 107 carries out the control for keeping the combustion state in the incinerator in a good state. In contrast, in a case where the determination result is NO in S16, the process in Fig. 10 ends without carrying out processing in S17.

[0108]

Note that it is possible to predetermine a determination criteria for S16 and also to predetermine a method of determining the control content in S17. For example, the control may be carried out when the predicted value of the lower calorific value calculated in S15 is outside a predetermined normal range (the determination result in S16 is YES). Further, in a case where the predicted value of the amount of heat generated is less than the lower limit of the normal range, the equipment control section 107 may carry out control for increasing the amount of heat generated (e.g., control to heat by a burner or to increase the amount of combustion air). In contrast, in a case where the predicted value of the

amount of heat generated is more than the upper limit of the normal range, the equipment control section 107 may carry out control for decreasing the amount of heat generated (e.g., control to decrease the amount of combustion air). This makes it possible to keep the combustion state in the incinerator in a good state.

[0109]

Embodiment 3

(Configuration of plant control device)

Fig. 11 is a block diagram illustrating an example of a configuration of a main part of a plant control device 1B in accordance with the present embodiment. The plant control device 1B is a device that controls equipment in an incineration plant on the basis of a waste feeding rate and movement data which has been generated from a plurality of time-series images each obtained by capturing an image of the hopper from above.

[0110]

Compared with the prediction device 1 and the prediction device 1A described above, the plant control device 1B is the same in that the movement data is generated from a plurality of time-series images each obtained by capturing an image of the hopper from above, whereas the plant control device 1B is different in that the plant control device 1B controls equipment without

prediction of properties of waste. Therefore, it is also possible to configure the plant control system 100 obtained by replacing, in Fig. 2, the prediction device 1 by the plant control device 1B.

5 [0111]

Unlike the prediction device 1 illustrated in Fig. 1, the plant control device 1B includes none of the standard movement amount calculation section 104, the property prediction section 105, and the influence prediction
10 section 106. The plant control device 1B, instead, includes a control content determination section 105B. Further, in the storage section 11 of the plant control device 1B, the standard movement amount calculation formula 112 is not stored, but instead, the control content determination
15 model 112B is stored.

[0112]

The control content determination section 105B determines the control content for the equipment in the waste incineration plant on the basis of the movement data
20 generated by a movement data generation section 103 and the waste feeding rate. For example, the control content determination section 105B can determine a control content of at least one selected from the group consisting of the following (1) to (5): (1) control of introduction of
25 waste into a hopper; (2) control of the waste feeding rate,

(3) control of a transfer speed (grate speed) of the waste in an incinerator, (4) control of combustion of the waste in the incinerator; and (5) control of stirring of the waste in a pit. The control content can include, for example, a control target and a control amount.

[0113]

Note that these controls are controls necessary for maintaining an appropriate combustion state. Therefore, the control content determination section 105B determines not to carry out control when there is no control that should be carried out in order to maintain the appropriate combustion state.

[0114]

More specifically, the control content determination section 105B determines the control content with use of a control content determination model 112B. The control content determination model 112B is a model constructed to be capable of determining the control content from the movement data and the waste feeding rate. For example, in a case where the control amount of the grate speed is to be determined, it is possible to use the control content determination model 112B, in which the movement amount and the waste feeding rate are explanatory variables and an optimum grate speed for maintaining an appropriate combustion state is an objective variable. Such a control

content determination model 112B can be constructed by multiple regression analysis or can be constructed by another algorithm such as a neural net.

[0115]

5 An equipment control section 107 then carries out the control, which has been determined by the control content determination section 105B, on the equipment in the waste incineration plant. As described above, the control content determination section 105B determines the control content on the basis of the movement data and the waste feeding rate. Therefore, the equipment control section 107 can be said to control the equipment in the waste incineration plant on the basis of the movement data and the waste feeding rate.

15 [0116]

 As described above, the plant control device 1B includes the movement data generation section 103 and the equipment control section 107. The movement data generation section 103 generates movement data, which indicates a movement state of waste, from a plurality of time-series images each obtained by capturing, from above, an image of a hopper in an incineration plant where the waste introduced into the hopper is fed to an incinerator at a specified waste feeding rate. The equipment control section 107 carries out, on the basis of the movement data

generated by the movement data generation section 103 and the waste feeding rate, control that is at least one selected from the group consisting of (1) control of introduction of the waste into the hopper; (2) control of the waste feeding rate; (3) control of the transfer speed of the waste in the incinerator; (4) control of combustion of the waste in the incinerator; and (5) control of stirring of the waste in the pit.

[0117]

As described above, a difference in properties of an incineration target object such as waste appears as a difference in movement state of the incineration target object captured in images. Then, the difference in the properties of the incineration target object affects the content of control necessary to maintain an appropriate combustion state of the incineration target object. Accordingly, from the movement state of the waste captured in the image, it is possible to determine the control necessary to maintain an appropriate combustion state of the waste. Therefore, with the above configuration, it is possible to carry out appropriate control in accordance with the properties of the waste, and therefore to contribute to improvement in operation of the incineration plant.

[0118]

(Flow of process)

A flow of a process (plant control method, method for controlling a plant) executed by the plant control device 1B will be described with reference to Fig. 12. Fig. 12 is a flowchart showing an example of the process executed by the plant control device 1B. Note that since the description of processing in S21 to S23 of Fig. 12 is identical to that of S1 to S3 of Fig. 6, the description will be omitted.

[0119]

In S24, the control content determination section 105B determines the control content with use of the control content determination model 112B. For example, the following are assumed: the movement data generated in S23 is data that indicates movement amounts; and the control content determination model 112B is a model in which the movement amount and the waste feeding rate are explanatory variables and a change amount of the waste feeding rate, which is optimal for maintaining an appropriate combustion state, is an objective variable. In this case, the control content determination section 105B determines the change amount of the waste feeding rate, which is optimal for maintaining an appropriate combustion state, from (a) the movement amount indicated by the movement data generated in S23 and (b) a value

obtained by inputting the waste feeding rate to the control content determination model 112B.

[0120]

5 In S25, the equipment control section 107 determines whether or not to carry out control for keeping the combustion state in the incinerator in a good state. In a case where a determination result is YES in S25, the process proceeds to S26, and in S26, the equipment control section 107 carries out control of the content
10 determined in S24. In contrast, in a case where the determination result is NO in S25, the process in Fig. 12 ends without carrying out processing in S26.

[0121]

15 Note that it is possible to predetermine a determination criteria for S25. For example, it may be determined to carry out control (YES in S25) unless it is determined in S24 that control is not to be carried out or the control amount is determined to be zero. Further, for example, in a case where the control content determination
20 model 112B used is constructed to output, together with the control content predicted to be optimal, a numerical value indicating the degree of certainty of that prediction, it can be determined that the control is to be carried out (YES in S25) if the degree of certainty is more than or equal
25 to a threshold value. Alternatively, for example, it is

possible to present, to an operator, the control content determined in S24 and make the operator input whether or not to execute the control.

[0122]

5 As described above, the plant control method in accordance with the present embodiment includes steps (S23) and (S26). In the step (S23), movement data, which indicates a movement state of the waste, is generated from a plurality of time-series images each obtained by
10 capturing, from above, an image of a hopper in an incineration plant in which waste introduced into the hopper is fed to an incinerator at a specified waste feeding rate. In the step (S26), on the basis of the movement data generated in the step (S23) and the waste feeding rate, at
15 least one selected from the group consisting of the following (1) to (5) is carried out: (1) control of introduction of the waste into the hopper; (2) control of the waste feeding rate; (3) control of a transfer speed of the waste in the incinerator; (4) control of combustion of
20 the waste in the incinerator; and (5) control of stirring of the waste in a pit. With this plant control method, it is possible to contribute to improvement in operation of the incineration plant.

[0123]

25 (Occurrence of bridging)

In the hopper, bridging may occur. In bridging, the waste in the hopper forms a bridge shape in the hopper and clogs the hopper. When bridging occurs, the movement amount of the waste in an upper portion of the hopper (at
5 a position at which bridging occurs and above the position) is significantly reduced or becomes zero, regardless of properties of the waste. Therefore, it is difficult to predict the properties of the waste from images that are captured while bridging is occurring.

10 [0124]

Therefore, the prediction devices 1 and 1A described in the above embodiments may be configured to include a bridge detection section that detects the occurrence of bridging, and may be configured not to predict the
15 properties of the waste in a case where the bridge detection section detects the occurrence of bridging. Further, the prediction devices 1 and 1A may be configured to hold a result of prediction of the properties of the waste while bridging is occurring, and to restart prediction of the
20 properties after the bridging is eliminated.

[0125]

The method of detecting the occurrence and elimination of bridging is not particularly limited. For example, the occurrence and elimination of bridging may
25 be detected on the basis of the movement amount of the

waste, which is indicated by the movement data generated by the movement data generation section 103. The plant control device 1B may be similarly configured. That is, the plant control device 1B may be configured to detect the occurrence of bridging and to hold control while bridging is occurring, and restart the control after the bridging has been eliminated.

[0126]

Conversely, it is also possible to detect the occurrence of bridging from the prediction result of the properties of the waste, by utilizing the fact that the occurrence of bridging affects the prediction result of the properties of the waste. For example, in a case where a difference between a predicted bulk density and a measured bulk density occurs, the prediction device 1A may determine that bridging occurs. Further, in a case where bridging continues for a long time, a lower calorific value is also influenced. Therefore, the prediction device 1A may determine that bridging occurs in a case where the predicted lower calorific value deviates from a straight line k1 shown in Fig. 9.

[0127]

[Variations]

A subject that executes each process described in the above embodiments can be any subject, and is not

limited to the examples described above. That is, it is possible to construct, with use of a plurality of devices which can communicate with each other, a system having the same functions as each of the prediction devices 1 and 1A and the plant control device 1B. For example, it is possible to have a configuration in which: an information processing device is caused to carry out processing in S1 to S3 in Fig. 6; the movement data generated is transmitted to another information processing device; and the another information processing device carries out processing in S4 to S8. The same applies to the processes shown in Figs. 9 and 12.

[0128]

[Software Implementation Example]

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

[0129]

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

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.

[0130]

5 The program can be stored in one or more non-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.

10 [0131]

 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
15 functions as the foregoing control blocks is formed. In addition, it is possible to realize the functions of the blocks by, for example, a quantum computer.

[0132]

 The present invention is not limited to the
20 embodiments, but can be variously altered by a skilled person in the 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.

Reference Signs List

[0133]

- 1 prediction device
- 103 movement data generation section
- 5 104 standard movement amount calculation section
- 105 property prediction section (prediction section)
- 1A prediction device
- 103 movement data generation section
- 105A bulk density prediction section (prediction section)
- 10 1B plant control device
- 103 movement data generation section
- 107 equipment control section

Claims

[Claim 1]

A prediction 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 an incineration plant where an incineration
target object introduced into the hopper is fed to an
incinerator at a specified rate, the movement data
10 indicating a movement state of the incineration target
object; and

a prediction section configured to predict properties
of the incineration target object to be incinerated, on the
basis of the rate and the movement data generated by the
15 movement data generation section.

[Claim 2]

The prediction device according to claim 1, wherein:

the movement data indicates a movement amount of
20 the incineration target object; and

the prediction section calculates, as a prediction
result, a difference between (a) the movement amount
which is indicated by the movement data generated by the
movement data generation section and (b) a standard
25 movement amount of the incineration target object at the

time when the incineration target object is fed to the incinerator at the rate.

[Claim 3]

5 The prediction device according to claim 2, further comprising

 a standard movement amount calculation section configured to calculate the standard movement amount, with use of a mathematical expression indicating a
10 relation between (a) the rate at which the incineration target object is fed to the incinerator and (b) the standard movement amount of the incineration target object at the time when the incineration target object is fed to the incinerator at the rate.

15 [Claim 4]

 The prediction device according to claim 1, wherein:
 the movement data indicates a movement amount of the incineration target object; and

20 the prediction section calculates, as a prediction result, a bulk density by a mathematical expression indicating a relation of (a) the movement amount which is indicated by the movement data generated by the movement data generation section, (b) the rate at which

the incineration target object is fed to the incinerator, and
(c) the bulk density of the incineration target object.

[Claim 5]

5 The prediction device according to claim 1, wherein:
the movement data indicates a movement amount of
the incineration target object; and
the prediction section calculates, as a prediction
result, a lower calorific value by a mathematical
10 expression indicating a relation of (a) the movement
amount which is indicated by the movement data generated
by the movement data generation section, (b) the rate at
which the incineration target object is fed to the
incinerator, and (c) the lower calorific value at the time
15 when the incineration target object is incinerated.

[Claim 6]

A plant control device comprising:
a movement data generation section configured to
20 generate movement data from a plurality of time-series
images each obtained by capturing, from above, an image
of a hopper in an incineration plant where an incineration
target object introduced into the hopper is fed to an
incinerator at a specified rate, the movement data

indicating a movement state of the incineration target object; and

an equipment control section configured to carry out control on the basis of the rate and the movement data generated by the movement data generation section, the control being at least one selected from the group consisting of (1) control of introduction of the incineration target object into the hopper; (2) control of the rate; (3) control of a transfer speed of the incineration target object in the incinerator; (4) control of combustion of the incineration target object in the incinerator; and (5) control of stirring of the incineration target object.

[Claim 7]

A method for predicting properties of an incineration target object, the method being executed by one or more information processing devices, the method comprising 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 an incineration plant where the incineration target object introduced into the hopper is fed to an incinerator at a specified rate, the movement data indicating a movement state of the incineration target object; and

predicting the properties of the incineration target object to be incinerated, on the basis of the rate and the movement data generated in the step of generating the movement data.

5

[Claim 8]

A method for controlling a plant, 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 an incineration plant where an incineration target object introduced into the hopper is fed to an incinerator at a specified rate, the movement data
15 indicating a movement state of the incineration target object; and

 carrying out control on the basis of the rate and the movement data generated in the step of generating the movement data, the control being at least one selected
20 from the group consisting of (1) control of introduction of the incineration target object into the hopper; (2) control of the rate; (3) control of a transfer speed of the incineration target object in the incinerator; (4) control of combustion of the incineration target object in the

incinerator; and (5) control of stirring of the incineration target object.

[Claim 9]

5 A prediction program for causing a computer to function as a prediction device according to claim 1, the prediction program causing the computer to function as the movement data generation section and the prediction section.

10

[Claim 10]

 A control program for causing a computer to function as a plant control device according to claim 6, the control program causing the computer to function as the movement data generation section and the equipment control section.

15