

## DESCRIPTION

### LOADING VOLUME RATIO MEASUREMENT APPARATUS, SYSTEM, METHOD AND PROGRAM

5

#### TECHNICAL FIELD

[0001]

#### (DESCRIPTION OF RELATED APPLICATION)

The present invention is based on claiming priority of Japanese Patent  
10 Application: 2020-216527 (filed on December 25, 2020), and the entire  
contents of the present application shall be incorporated and stated in  
the present application by reference.

The present invention relates to a loading volume ratio measurement  
apparatus, system, method, and program.

#### 15 BACKGROUND ART

[0002]

In some transportation companies, in order to improve  
transportation efficiency, a baggage (luggage, package, cargo) is loaded  
into a container (including a box-type cargo bed such as a van body and  
20 a wing body) sequentially from a back side to a front side at a truck  
berth, and they are trying to carry out transportation in a state close to  
a loading volume ratio 100%. Also, when unloading, all of the baggage  
is moved from the container to an inner warehouse at the truck berth  
and they are trying to become a state of a loading volume ratio 0%.  
25 Further, the loading volume ratio is measured visually by a driver, and  
the measured loading volume ratio is reported from the driver to a  
manager.

[0003]

However, visual measurement of the loading volume ratio tends  
30 to cause individual differences, and it is difficult to grasp a correct  
value. Also, while baggage is loaded at a preceding vehicle, there may  
be another waiting vehicle in the truck berth. Since in that case, the  
loading volume ratio of the preceding vehicle is reported immediately

before departure after loading of the preceding vehicle is completed, a waiting vehicle starts moving after the preceding vehicle departs, and in a vast truck berth, reporting the loading volume ratio causes time loss.

5 [0004]

From these phenomena, by automatically monitoring the loading volume ratio, it is desirable that it is possible to eliminate individual difference due to measurement of the loading volume ratio and a labor of reporting the measured loading volume ratio, and it is possible to  
10 guide the position of the preceding vehicle becoming close to loading volume ratio 100% to the waiting vehicle in advance.

[0005]

As a technology for automatically monitoring a loading volume ratio, it is conceivable to apply a technique for recognizing volume of  
15 baggage by using point group data (three-dimensional data) imaged (photographed, shot) or scanned by imaging parts (cameras, sensors) at multiple points as described in Patent Literatures (PTLs) 1 to 4,

PATENT LITERATURE

[0006]

20 [PTL 1] JP6577687B

[PTL 2] JP6511681B

[PTL 3] JP2020-60451A

[PTL 4] JP2017-175483A

SUMMARY

25 TECHNICAL PROBLEM

[0007]

The following analysis is given by the inventors of the present application.

[0008]

30 However, in the techniques described in PTLs 1 to 4, a plurality of imaging parts are required to recognize a volume of baggage if a plurality of imaging parts are used, there is a possibility that a space for mounting the imaging parts increases, a space where baggage cannot

be placed in the container increases, and economy deteriorates. Also, even if a plurality of imaging parts are used, there is a possibility that a dead angle of each imaging part cannot be supplemented by specs and mounting positions of the imaging parts.

5 [0009]

In addition, the techniques described in PTLs 1 to 4 are limited to recognizing shape, edge, and sizes of baggage in the front row that can be imaged, and there is a possibility that a situation of the entire baggage in the container (especially, a situation of a baggage in the place that cannot be imaged) cannot be recognized accurately.

10 [0010]

Further, in the techniques described in PTLs 1 to 4, it is assumed that at least point group data can be acquired within the field angle to some extent, so there is a possibility that when a baggage approaches to close range of the imaging part, it is impossible to image the baggage, and a situation of the baggage cannot be accurately recognized at the close range of the imaging part. In other words, unlike an analog camera, a digital camera or the like that images non-point group data, an imaging part such as a 3D sensor that images point group data cannot image, due to specifications, at a short distance of several tens of centimeters to 1 m due to a constraint of a mechanism for distance measurement such as ToF (Time of Flight) and stereo. In particular, when there are multiple imaging parts, it is easy for the baggage to approach to a close range of the imaging part, and the dead angle of one imaging part cannot be compensated by another imaging part, and a possibility of not being able to accurately recognize a situation of the baggage at a close range of the imaging part increases.

25 [0011]

Furthermore, in the technique described in PTL 3, when there is a baggage at a close range of the sensor, the baggage in the dead angle of the sensor is uniformly interpolated, so the baggage closest to the sensor and the other baggage around the baggage are on the same surface, not-existable baggage is interpolated and a load amount of the baggage

is measured, and there is a possibility that a divergence between the measured load amount and the actual load amount increases.

[0012]

It is a main object of the present invention to provide a loading  
5 volume ratio measurement apparatus, system, method, and program that  
can contribute to suppressing a divergence between a measured load  
amount and an actual load amount of baggage on a volume base without  
using a multiple of imaging parts even if there is a baggage at a close  
range of an imaging part.

## 10 SOLUTION TO PROBLEM

[0013]

A loading volume ratio measurement apparatus according to a  
first aspect comprises: a monitoring area designation part configured to  
acquire a point group existing in a monitoring area in which an area in  
15 which a measurement object(s) is loaded is designated in a  
predetermined space among imaging data obtained by imaging the  
predetermined space using an imaging part; a voxelization part  
configured to create array data obtained by validating a voxel(s) in  
which a number of points of the point group exist at a predetermined  
20 number or more into (as) a valid voxel(s) among voxels in voxel grids  
obtained by dividing the monitoring area by a voxel having a voxel side  
length designated in advance; a field angle occlusion voxel calculation  
part configured to calculate a dead angle invalid voxel position  
information related to a position of the dead angle invalid voxel(s) that  
25 cannot be visualized in an occlusion portion that is a dead angle of the  
imaging part in the voxel grids within the array data, based on imaging  
part mounting position information related to a position where the  
imaging part is mounted, field angle information related to a field angle  
of the imaging part, the monitoring area, and the voxel side length; an  
30 array processing part configured to create estimated array data obtained  
by estimating a valid voxel(s) in a state excluding an occlusion portion  
in which an obstacle(s) in the front hides a measurement object(s) in  
the back of the obstacle(s) and makes the measurement object(s)

invisible, based on the plurality of array data within a prespecified interval time, and when satisfying a predetermined condition, creating loading array data obtained by validating all of the dead angle invalid voxel(s) in the left or right direction or downward direction of the frontmost valid voxel(s) in the estimated array data into (as) a valid voxel(s) and validating all of the invalid voxel(s) in a back direction of all of the valid voxel(s) after validation into a valid voxel(s); and a loading volume ratio calculation part configured to calculate a loading volume ratio which is a ratio of a volume of the measurement object loaded in the monitoring area relative to a total volume in the monitoring area based on the loading array data.

[0014]

A loading volume ratio measurement system according to a second aspect comprises: an imaging part configured to output imaging data obtained by imaging a predetermined space; and a loading volume ratio measurement apparatus according to the first aspect.

[0015]

A loading volume ratio measurement method according to a third aspect is a method of measuring a loading volume ratio using a hardware resource(s), and comprises: acquiring a point group existing in a monitoring area in which an area in which a measurement object(s) is loaded is designated in a predetermined space among imaging data obtained by imaging the predetermined space using an imaging part; creating array data obtained by using a voxel(s) in which a number of points of the point group exist at a predetermined number or more into (as) a valid voxel(s) among voxels in voxel grids obtained by dividing the monitoring area by a voxel having a voxel side length designated in advance; calculating a dead angle invalid voxel position information related to a position of the dead angle invalid voxel(s) that cannot be visualized in an occlusion portion that is a dead angle of the imaging part in the voxel grids within the array data, based on imaging part mounting position information related to a position where the imaging part is mounted, field angle information related to a field angle of the

imaging part, the monitoring area, and the voxel side length; creating  
estimated array data obtained by estimating a valid voxel(s) in a state  
excluding an occlusion portion in which an obstacle(s) in the front hides  
a measurement object(s) in the back of the obstacle(s) and makes the  
5 measurement object(s) invisible, based on the plurality of array data  
within a prespecified interval time, and when satisfying a predetermined  
condition, creating loading array data obtained by validating all of the  
dead angle invalid voxel(s) in the left or right direction or downward  
direction of the frontmost valid voxel(s) in the estimated array data into  
10 (as) a valid voxel(s) and validating all of the invalid voxel(s) in a back  
direction of all of the valid voxel(s) after validation into a valid  
voxel(s); and calculating a loading volume ratio which is a ratio of a  
volume of the measurement object loaded in the monitoring area relative  
to a total volume in the monitoring area based on the loading array data.  
15 [0016]

A program according to a fourth aspect is a program causing a  
hardware resource(s) to execute measuring a loading volume ratio,  
wherein the program causes a hardware resource(s) to execute: acquiring  
a point group existing in a monitoring area in which an area in which a  
20 measurement object(s) is loaded is designated in a predetermined space  
among imaging data obtained by imaging the predetermined space using  
an imaging part; creating array data obtained by using a voxel(s) in  
which a number of points of the point group exist at a predetermined  
number or more into (as) a valid voxel(s) among voxels in voxel grids  
25 obtained by dividing the monitoring area by a voxel having a voxel side  
length designated in advance; calculating a dead angle invalid voxel  
position information related to a position of the dead angle invalid  
voxel(s) that cannot be visualized in an occlusion portion that is a dead  
angle of the imaging part in the voxel grids within the array data, based  
30 on imaging part mounting position information related to a position  
where the imaging part is mounted, field angle information related to a  
field angle of the imaging part, the monitoring area, and the voxel side  
length; creating estimated array data obtained by estimating a valid

voxel(s) in a state excluding an occlusion portion in which an obstacle(s) in the front hides a measurement object(s) in the back of the obstacle(s) and makes the measurement object(s) invisible, based on the plurality of array data within a prespecified interval time, and when  
5 satisfying a predetermined condition, creating loading array data obtained by validating all of the dead angle invalid voxel(s) in the left or right direction or downward direction of the frontmost valid voxel(s) in the estimated array data into (as) a valid voxel(s) and validating all of the invalid voxel(s) in a back direction of all of the valid voxel(s)  
10 after validation into a valid voxel(s); and calculating a loading volume ratio which is a ratio of a volume of the measurement object loaded in the monitoring area relative to a total volume in the monitoring area based on the loading array data.

[0017]

15 The program can be recorded on a computer-readable storage medium. The storage medium can be non-transient such as semiconductor memory, hard disk, magnetic recording medium, optical recording medium, and the like. Also, the present disclosure can also be embodied as a computer program product. The program is input from an  
20 input apparatus or an outside to a computer apparatus via communication interface, is stored in a storage device, drives a processor in accordance with predetermined steps or processings, can be caused to displaying results of processing including intermediate states as necessary in stages via a display apparatus, or can be communicated with the outside  
25 via a communication interface. A computer apparatus for this purpose, as an example, typically comprises a processor, a storage device, an input apparatus, a communication interface, and a display apparatus as necessary, which are connectable to each other by a bus.

#### EFFECTS OF INVENTION

30 [0018]

According to the first to fourth aspects, it is possible to contribute to suppressing a divergence between a measured load amount and an actual load amount of baggage on a volume base without using a

multiple of imaging parts.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0019]

[FIG. 1] FIG. 1 is a block diagram schematically showing a configuration of a loading volume ratio measurement system according to a first embodiment.

[FIG. 2] Fig. 2 is a block diagram schematically showing a configuration of a loading volume ratio measurement apparatus in the loading volume ratio measurement system according to the first embodiment.

[FIG. 3] FIG. 3 is an image diagram schematically showing a range that can be imaged by an imaging part, (A) is a perspective view, (B) is a view viewed from an arrow D1 in FIG. 3(A), and (C) is a view viewed from an arrow D2 in FIG. 3(A).

[FIG. 4] FIG. 4 is an image diagram schematically showing an example of a situation in which a baggage in a container is imaged by the imaging part, (A) is a diagram viewed from the arrow D1 in FIG. 3(A), and (B) is a diagram viewed from the arrow D2 of FIG. 3(A).

[FIG. 5] FIG. 5 is an image diagram of an example of a point group when the baggage in the container is imaged by the imaging part, (A) is a diagram viewed from the arrow D1 in FIG. 3(A), (B) is a diagram viewed from the arrow D2 in FIG. 3(A), and (C) is a diagram viewed from an arrow D3 in FIG. 3(A).

[FIG. 6] FIG. 6 is an image diagram viewed from the arrow D2 of FIG. 3(A), the image diagram schematically showing a range that can be visualized from imaging data imaged by the imaging part.

[FIG. 7] FIG. 7 is an image diagram schematically showing changes in visualization information of the baggage that can be visualized by the imaging part during processes of loading the baggage in the container.

[FIG. 8] FIG. 8 is an image diagram of a first example schematically showing a flow from imaging to voxel interpolation by the loading volume ratio measurement apparatus in the loading volume ratio measurement system according to the first embodiment.

[FIG. 9] FIG. 9 is an image diagram of a second example schematically

showing a flow from imaging to voxel interpolation by the loading volume ratio measurement apparatus in the loading volume ratio measurement system according to the first embodiment.

[FIG. 10] FIG. 10 is an image diagram of a third example schematically showing a flow from imaging to voxel interpolation by the loading volume ratio measurement apparatus in the loading volume ratio measurement system according to the first embodiment.

[FIG. 11] FIG. 11 is a flow chart diagram schematically showing operations of the loading volume ratio measurement apparatus in the loading volume ratio measurement system according to the first embodiment.

[FIG. 12] FIG. 12 is a flow chart diagram schematically showing detailed operations of step A7[sic., 8] in FIG. 11 of the loading volume ratio measurement apparatus in the loading volume ratio measurement system according to the first embodiment.

[FIG. 13] FIG. 13 is a block diagram schematically showing a configuration of a loading volume ratio measurement apparatus according to a second embodiment.

[FIG. 14] FIG. 14 is a block diagram schematically showing a configuration of hardware resources.

## EXAMPLE EMBODIMENTS

[0020]

Hereinafter, embodiments will be described with reference to drawings. It should be noted that when reference numerals are attached to the drawings in the present application, they are solely for a purpose of helping to understand, and are not intended to limit the embodiments shown in the drawings. Also, the following embodiments are only examples, and do not limit the present invention. Further, connection lines between blocks in the drawings and the like referred to in the following description include both bidirectional and unidirectional connections. The unidirectional arrows schematically show flows of main signals (data) and do not exclude bidirectionality. Furthermore, in circuit diagrams, block diagrams, internal configuration diagrams,

connection diagrams, etc. disclosed in the present application, an input port and an output port exist at the input end and the output end of each connection line, respectively, although not explicitly shown. The input/output interface is the same. The program is executed via a computer apparatus, and the computer apparatus comprises, for example, a processor, a storage device, an input apparatus, a communication interface, and a display apparatus as necessary. The computer apparatus is configured to be able to communicate with an internal or external apparatus (including computer) via the communication interface, whether wired or wireless.

[0021]

[First embodiment]

A loading volume ratio measurement system according to a first embodiment will be described with reference to drawings. FIG. 1 is a block diagram schematically showing a configuration of the loading volume ratio measurement system according to the first embodiment. FIG. 2 is a block diagram schematically showing a configuration of a loading volume ratio measurement apparatus in the loading volume ratio measurement system according to the first embodiment.

[0022]

The loading volume ratio measurement system 1 is a system for measuring a loading volume ratio (loading volume is also possible) of a baggage 20 (measurement object) inside a container 11 (equivalent to a monitoring area) of a truck 10 (see FIG. 1). The loading volume ratio measurement system 1 can be used to manage transportation in fields of transportation such as truck, aircraft, and ship, and in fields of factory. In the loading volume ratio measurement system 1, an imaging part 300 and a loading volume ratio measurement apparatus 200 are connected via a network 400 so as to be communicable. In the loading volume ratio measurement system 1, the loading volume ratio measurement apparatus 200 measures a loading volume ratio of the baggage 20 in the container 11 of the truck 10 based on imaging data (100 in FIG. 2) imaged by the imaging part 300. The loading volume ratio measurement system 1

quantifies the loading volume ratio according to loading status or unloading status of the baggage 20 in the container 11. The loading volume ratio measurement system 1 displays a value of the measured loading volume ratio together with visualization information (see FIG. 7) that visualizes the imaging data 100.

[0023]

The imaging part 300 is a function part that senses and images a surface of the baggage 20 in the container 11 of the truck 10 (see FIG. 1). The imaging part 300 is connected to the loading volume ratio measurement apparatus 200 via the network 400 so as to be capable of wireless communication (wired communication is also possible). The imaging part 300 outputs the imaging data (100 in FIG. 2) obtained by imaging the baggage 20 to the loading volume ratio measurement apparatus 200. The imaging data 100 is point group data (three-dimensional data) drawn with a point group (three-dimensional coordinates of a large number of points). The imaging part 300 can be selected according to environmental conditions such as imaging distance, field angle, indoors/outdoors, presence or absence of sunlight, and customer requests necessary for measuring the loading volume ratio. Also, as the imaging part 300, products sold by various manufacturers can be used. As the imaging part 300, for example, a stereo camera, a ToF (Time of Flight) camera, a 3D-LIDAR (Three Dimensions—Laser Imaging Detection and Ranging), or the like can be used. The imaging part 300 is attached (or may be mounted) at a position where the baggage 20 in the container 11 of the truck 10 can be imaged, for example, the imaging part 300 can be attached to the container 11, a ceiling or wall surface of a truck berth contacted with the truck 10 for loading and unloading the baggage between the truck 10 and a warehouse. There may be one imaging part 300 if the monitoring area can be covered by one imaging part 300, and a plurality of imaging parts may be provided when there is the monitoring area in a plurality of locations or a plurality of directions.

[0024]

The network 400 is a wired or wireless communication network that communicably connects the imaging part 300 and the loading volume ratio measurement apparatus 200. As the network 400, for example, a communication network such as a PAN (Personal Area Network), a LAN (Local Area Network), a MAN (Metropolitan Area Network), a WAN (Wide Area Network), or a GAN (Global Area Network) can be used.

[0025]

The loading volume ratio measurement apparatus 200 is an apparatus that measures the loading volume ratio of the baggage 20 in the container 11 of the truck 10 based on the imaging data 100 of a predetermined space imaged by the imaging part 300 (see FIGS. 1 and 2). Here, the loading volume ratio means a ratio (percentage) of a volume of the baggage 20 loaded to a total volume inside the container 11. The loading volume ratio measurement apparatus 200 has a function of visualizing the baggage 20 in the container 11. The loading volume ratio measurement apparatus 200 is used by an observer (watcher). The loading volume ratio measurement apparatus 200 can use an apparatus (computer apparatus) having function parts (for example, a processor, a storage device, an input apparatus, a communication interface, and a display apparatus) that configure a computer. As the loading volume ratio measurement apparatus 200, for example, hardware resources such as a calculator, a personal computer, a notebook personal computer, a tablet terminal, etc. can be used. The loading volume ratio measurement apparatus 200 realizes a preprocessing part 210, a loading volume management part 220, a result generation part 230, and an interface part 240 by executing a predetermined program (software).

[0026]

The preprocessing part 210 is a function part that performs predetermined preprocessing (here, format conversion and noise removal) on the imaging data 100 from the imaging part (300 in FIG. 1) (see FIG. 2). The preprocessing part 210 preprocesses the imaging data 100 from the imaging part (300 in FIG. 1) and outputs the preprocessed

imaging data 100 towards a monitoring area designation part 221 of the loading volume management part 220 and a display part 242 of the interface part 240. The preprocessing part 210 comprises a format conversion part 211 and a noise removal part 212.

5 [0027]

The format conversion part 211 is a function part that converts a format of the imaging data 100 which varies depending on a type of the imaging part (300 in FIG. 1) to a common format that can be commonly used in the loading volume ratio measurement apparatus 200 (see FIG. 10 2). The Format conversion part 211 outputs the imaging data 100 converted to a common format towards the noise removal part 212.

[0028]

The noise removal part 212 is a function part that removes noise (point group unnecessary for measurement) from a point group in the 15 imaging data 100 from the format conversion part 211 (see FIG. 2). The noise removal part 212 outputs the imaging data 100 with noise-removed towards the monitoring area designation part 221 of the loading volume management part 220 and the display part 242 of the interface part 240. As a noise removal method, for example, smoothing processing, filtering 20 (e.g., moving average filter processing, median filter processing, etc.), outlier removal processing (e.g., outlier removal processing by chi-square test), and the like are included.

[0029]

The loading volume management part 220 is a function part that 25 manages the loading volume of the baggage (20 in FIG. 1) in the container (11 in FIG. 1) (see FIG. 2). The loading volume management part 220 creates loading array data 112 based on the imaging data 100 from the noise removal part 212 of the preprocessing part 210 and operation information from the operation part 241 of the interface part 30 240. The created loading array data 112 is output towards the loading volume ratio calculation part 232 and the voxel visualization part 233 of the result generation part 230. The loading volume management part 220 comprises a monitoring area designation part 221, a voxelization

part 222, an array processing part 223, an array data group storage part 224, a field angle occlusion voxel calculation part 225, and an imaging part specification data storage part 226.

[0030]

5           The monitoring area designation part 221 is a function part that acquires the point group existing in a monitoring area (for example, a space in the container 11) designated by a user by using the operation part 241 of the interface part 240 among the imaging data 100 from the noise removal part 212 of the preprocessing part 210. Here, the  
10   monitoring area means an area in which a change of the loading volume of the baggage 20 (measurement object) is monitored and is an area in which the baggage 20 (measurement object) is loaded in a predetermined space among the imaging data obtained by imaging the predetermined space by the imaging part 300. The monitoring area designation part 221  
15   outputs the point group in the monitoring area of the acquired imaging data 100 towards the voxelization part 222.

[0031]

          The voxelization part 222 is a function part that creates an array data 111 by voxelizing (processing into voxels configured of cubes) the  
20   point group in the monitoring area of the imaging data 100 acquired by the monitoring area designation part 221 (see FIG. 2). The voxelization part 222 creates virtual voxel grids (three-dimensional array of voxels) obtained by dividing the monitoring area of the imaging data 100 acquired by the monitoring area designation part 221 by a voxel(s)  
25   having a voxel side length (one side length of a voxel related to a cube) designated by the user by using the operation part 241 of the interface part 240. Errors can be suppressed by appropriately adopting a length sufficiently smaller than a minimum dimension of the baggage 20 as the voxel side length. Here, as the point group in the monitoring area of the  
30   imaging data 100 acquired by the monitoring area designation part 221, only part (part where the point group is dense) of the imaging part 300 side (front side) of the baggage 20 is mainly obtained based on resolution issues. and the part in the inner (back) direction (i.e., behind

the baggage as seen from the imaging part) becomes a blank (portion where the point group is sparse or empty). Therefore, the voxelization part 222 creates the array data 111 obtained by validating voxels in which a number of points of the point group in the monitoring area of the imaging data 100 exist at a predetermined number (for example, three) or more to valid voxels (see valid voxels of FIG. 8(C), FIG. 9(C) and FIG. 10(C)) and invalidating voxels in which number of points of the point group is less than the predetermined number to invalid voxels (see invalid voxels of FIGS. 8(C), 9(C) and 10(C)), among the created voxel grids. The valid voxels correspond to the voxels of the filled-out part of the “visualization information” in FIG. 7. The array data 111 may relate not only binary information indicating whether each voxel in the voxel grid is valid or invalid, but also information relating to the number of points of the point group existing in each voxel, to each voxel and relate information of volumetric according to the number of points in the point group existing in each voxel, to each voxel. The voxelization part 222 outputs the created array data 111 towards the array processing part 223.

[0032]

The array processing part 223 is a function part that performs array processing of voxels based on the array data 111 (see FIG. 2). The array processing part 223 acquires the array data 111 from the voxelization part 222 and acquires the dead angle invalid voxel position information from the field angle occlusion voxel calculation part 225. The array processing part 223 creates the array data group 110 by arranging and relating array data 111 chronologically, per each interval time designated by the user by using the operation part 241 of the interface part 240, based on the acquired array data 111 and the dead angle invalid voxel position information. The array processing part 223 stores the created array data group 110 in the array data group storage part 224.

[0033]

The array processing part 223 creates an estimated array data

obtained by estimating valid voxels in a state excluding an occlusion portion in which an obstacle(s) (worker, trolley, baggage under loading, etc.) in the front hides the loaded baggage 20 located behind the obstacle and makes the loaded baggage 20 invisible for each array data group 110 by comparing each array data 111 of the array data group 110 stored in the array data group storage part 224.

[0034]

Here, in creating the estimated array data, by comparing, for example, between the array data 111 in one array data group 110, when a position in a left or right direction (for example, X-axis direction) and an up-down direction (for example, Y-axis direction) is the same and there are valid voxels at a different position in the front-back direction (for example, Z-axis direction) or the same position, the innermost (innermost of front-back direction in the same positions in the left or right direction and the up-down direction) valid voxel among those valid voxels can be selected.

[0035]

Also, in creating the estimated array data, by comparing, for example, between the array data 111 in one array data group 110, when a number of invalid voxels is greater than a number of valid voxels at a specific position, the voxels at the specific position can be invalidated into invalid voxels, and when the number of valid voxels is greater than the number of invalid voxels at the specific position, the voxels at the specific position can be validated into valid voxels.

[0036]

In creating the estimated array data, not only comparison between the array data 111, but also labeling, machine learning, and the like may be used. The array processing part 223 may hold the created estimated array data.

[0037]

The array processing part 223 creates loading array data 112 based on the held estimated array data.

[0038]

Here, in creating the loading array data 112, invalid voxels (dead angle invalid voxels) in the occlusion portion that is a dead angle are estimated by also referring to the dead angle invalid voxel position information from the field angle occlusion voxel calculation part 225 in addition to the conventional array data 111 and the array data group 110 for referring to past data. The dead angle invalid voxels are estimated based on conditions such as whether there are dead angle invalid voxels in the voxel grid in the past or present array data up to the part contacting with the occlusion portion that becomes the dead angle. The estimated dead angle invalid voxels are validated (interpolated) into (as) valid voxels when satisfying a predetermined condition. For example, when portions in which valid voxels exist in the past data are indicated as invalid voxels and there are no valid voxels also on the inner (back) side in the direction away from the imaging part 300, the dead angle invalid voxels on the front side that cannot be imaged are validated. Also, all invalid voxels locating directly behind the valid voxels that appear as if floating in the air are validated. Further, from the viewpoint of preventing load collapse, a baggage is normally loaded from the left or right wall side, so when there is a valid voxel(s) in the front central part and there is a dead angle invalid voxel(s) in the left or right direction thereof, all of the dead angle invalid voxel(s) in the left or right direction are validated.

[0039]

Also, in creating the loading array data 112, as the point group in the monitoring area of the imaging data 100 acquired by the monitoring area designation part 221, only a part of the sensor side (front side) of the baggage 20 (the point group is dense) is mainly acquired. Since a part in the inner (back) direction is blank (part where the point group is sparse or empty), it is necessary to interpolate the part in the inner direction. Therefore, as one method of interpolating a part in the inner direction, the array processing part 223 can interpolate so that all voxels on the back side (back side in the front-back direction in the same position in the left or right and up-down directions) from

the valid voxel in the estimated array data are uniformly validated into (as) valid voxels. The interpolation here assumes that the baggage 20 are basically not packed (loaded) with intervening gaps.

[0040]

5           In addition, as another method of interpolating a part in the inner (back) direction, the array processing part 223 can interpolate so that voxels at a specific position are validated into valid voxels, when the voxels at the specific position are indicated as invalid voxels in the latest estimated array data whereas indicated as valid voxels in the past  
10           estimated array data. Further, when the voxels at the specific position are indicated as valid voxels in the latest estimated array data although indicated as invalid voxels in the past estimated array data, judging as a new baggage 20 has been added, the array processing part 223 can select valid voxels at the specific position among voxels. Also, when  
15           both the latest estimated array data and the past estimated array data in the voxels at the specific position are indicated as valid voxels, judging as the baggage 20 continues to exist, the array processing part 223 can select valid voxels among voxels at the specific position. Furthermore, when both the latest estimated array data and the past estimated array  
20           data in the voxel at the specific position are indicated as invalid voxels, judging as the baggage 20 has been not existing from the past, the array processing part 223 can select invalid voxels among voxels at the specific position. Another method of interpolating the part in the inner direction may be performed by combining with one method of  
25           interpolating the part in the inner direction.

[0041]

          The array processing part 223 outputs the created loading array data 112 towards the loading volume ratio calculation part 232 and the voxel visualization part 233 of the result generation part 230. The  
30           array processing part 223 may hold the created loading array data 112 and use the held loading array data 112 when creating new loading array data 112.

[0042]

The array data group storage part 224 is a function part that stores the array data group 110 created by the array processing part 223 chronologically (see FIG. 2). The array data group storage part 224 writes or reads the array data group 110 according to an operation of the array processing part 223.

[0043]

The field angle occlusion voxel calculation part 225 is a function part that calculates positions of invalid voxels in an occlusion portion caused by a field angle of the imaging part 300. The field angle occlusion voxel calculation part 225 acquires an imaging part specification data 113 (imaging part mounting position information and field angle information) from the imaging part specification data storage part 226. The field angle occlusion voxel calculation part 225 acquires monitoring area and voxel side length designated by the user by using the operation part 241 of the interface part 240. The field angle occlusion voxel calculation part 225 calculates position information (dead angle invalid voxel position information) of invalid voxels (see FIG. 6) that cannot be visualized in an occlusion portion that is a dead angle of the imaging part 300 in the voxel grid in the array data 111 based on the acquired imaging part mounting position information, field angle information, monitoring area, and voxel side length. The field angle occlusion voxel calculation part 225 outputs the calculated dead angle invalid voxel position information towards the array data group storage part 224.

[0044]

The imaging part specification data storage part 226 is a function part that stores the imaging part specification data 113 (see FIG. 2). The imaging part specification data storage part 226 reads out the imaging part specification data 113 according to an operation of the field angle occlusion voxel calculation part 225. The imaging part specification data 113 is preset data and includes imaging part mounting position information and field angle information. The imaging part mounting position information is information related to a position at

which the imaging part 300 is mounted. As the imaging part mounting position information, for example, information relating to coordinates at which the imaging part 300 in the container 11 is mounted can be used. The field angle information is information relating to a horizontal field angle, a vertical field angle, and a swing angle (angle of optical axis) of the imaging part 300.

[0045]

The result generation part 230 is a function part that generates a result related to the loading volume ratio chronologically based on the loading array data 112 from the array processing part 223 of the loading volume management part 220 (see FIG. 2). The result generation part 230 comprises a warning value designation part 231, a loading volume ratio calculation part 232 and a voxel visualization part 233.

[0046]

The warning value designation part 231 is a function part that designates a warning value designated by the user by using the operation part 241 of the interface part 240 to the loading volume ratio calculation part 232 or the voxel visualization part 233 (see FIG. 2). Here, the warning value is a threshold of a condition for warning. For example, the warning value designation part 231 designates a warning value of "90%" to the loading volume ratio calculation part 232 in case of warning (for example, communicating to a waiting vehicle at a truck berth) when the loading volume ratio is "90%" or more. Also, the warning value designation part 231 designates a warning value of "2 m" to the voxel visualization part 233 in case of warning (for example, preventing load collapse in the container 11) when a change (difference) in height between the baggage 20 at the front and the baggage 20 at the inner (back) side in the container 11 is "2m" or more.

[0047]

The loading volume ratio calculation part 232 is a function part that calculates a loading volume ratio based on the loading array data 112 from the array processing part 223 of the loading volume management part 220 (see FIG. 2). The loading volume ratio calculation

part 232 calculates a loading volume ratio in a process in which the baggage 20 are sequentially loaded from the inner (back) side of the container 11 or in a process in which the baggage 20 are unloaded from the front side. The loading volume ratio can be calculated, for example,  
5 by calculating a ratio (percentage) of a number of valid voxels to a total number of voxels (regardless of whether they are indicated as valid voxels or invalid voxels) in the loading array data 112. The loading volume ratio calculation part 232 outputs information related to the calculated loading volume ratio towards the display part 242. When the  
10 calculated loading volume ratio is a warning value (for example, loading volume ratio of 90%) or more designated by the warning value designation part 231, the loading volume ratio calculation part 232 outputs warning display information together with information related to the calculated loading volume ratio towards the display part 242.

15 When it is inappropriate to consider a height inside the container 11 such that the baggage 20 has an irregular shape, and so on, that is, when the entire floor surface of the container 11 is occupied by a baggage 20, even if there is a space above the baggage 20, it may be considered that the loading volume ratio is 100%.

20 [0048]

The voxel visualization part 233 is a function part that creates visualization information by visualizing valid voxels based on the loading array data 112 from the array processing part 223 of the loading volume management part 220 (see FIG. 2). The voxel visualization part  
25 233 creates visualization information by drawing grid lines on the image of the loading array data 112 in order to visualize valid voxels. This makes it possible to visualize the loading status, which cannot be confirmed by point groups alone. The voxel visualization part 233 outputs the created visualization information toward the display part  
30 242. The voxel visualization part 233 outputs warning display information together with the generated visualization information towards the display part 242 when there is a part with a warning value (for example, height change (difference) of 2 m) or more designated by

the warning value designation part 231 in the created visualization information.

[0049]

The interface part 240 is a function part that exchanges information between the user and the loading volume ratio measurement apparatus 200 (see FIG. 2). The interface part 240 comprises an operation part 241 and a display part 242.

[0050]

The operation part 241 is a function part that receives user's operations (see FIG. 2). The operation part 241 outputs data (e.g., characters, numbers, positions, areas, etc.) input by user's operation (e.g., keyboard operation, mouse click operation, touch panel tap operation, etc.) towards the monitor region designation part 221, the voxelization part 222, the array processing part 223 or the field angle occlusion voxel calculation part 225 of the loading volume management part 220, or the warning value designation part 231 of the result generation part 230. The operation part 241 designates a monitoring area to the monitoring area designation part 221 by user's operation. The operation part 241 instructs the voxel side length to the voxelization part 222 by user's operation. The operation part 241 instructs the interval time to the array processing part 223 by user's operation. The operation part 241 designates (the same designation as the designation to the monitoring area designation part 221 and the voxelization part 222) the monitoring area and the voxel side length to the field angle occlusion voxel calculation part 225 by user's operation. The operation part 241 designates the warning value to the warning value designation part 231 by user's operation. The operation part 241 instructs the start/end of the overall processing in this configuration function by the user's operation.

[0051]

The display part 242 is a function part that displays various information (see FIG. 2). The display part 242 displays the imaging data 100 after preprocessing from the noise removal part 212 of the

preprocessing part 210. The display part 242 displays the loading volume ratio and the warning display information from the loading volume ratio calculation part 232 of the result generation part 230. The display part 242 displays visualization information and warning display information from the voxel visualization part 233 of the result generation part 230. As a method of displaying the warning display information, for example, the background color can be changed or blinked. The information displayed on the display part 242 may be output by voice using a speaker, printed by a printer, or transmitted to another terminal.

[0052]

Next, the interpolation of the occlusion portion, which is a dead angle caused by the specifications of the imaging part is explained, using drawings. FIG. 3 is an image diagram schematically showing a range that can be imaged by an imaging part, (A) is a perspective view, (B) is a view viewed from an arrow D1 in FIG. 3(A), and (C) is a view viewed from an arrow D2 in FIG. 3(A). FIG. 4 is an image diagram schematically showing an example of a situation in which a baggage in a container is imaged by the imaging part, (A) is a diagram viewed from the arrow D1 in FIG. 3(A), and (B) is a diagram viewed from the arrow D2 of FIG. 3(A). FIG. 5 is an image diagram of an example of a point group when the baggage in the container is imaged by the imaging part, (A) is a diagram viewed from the arrow D1 in FIG. 3(A), (B) is a diagram viewed from the arrow D2 in FIG. 3(A), and (C) is a diagram viewed from an arrow D3 in FIG. 3(A). FIG. 6 is an image diagram viewed from the arrow D2 of FIG. 3(A), the image diagram schematically showing a range that can be visualized from imaging data imaged by the imaging part. FIG. 7 is an image diagram schematically showing changes in visualization information of the baggage that can be visualized by the imaging part during processes of loading the baggage in the container. FIGS. 8 to 10 are image diagrams schematically showing flows from imaging to voxel interpolation by the load area ratio measurement apparatus in the load area ratio measurement system according to the

first embodiment.

[0053]

The imaging part 300 has field angles (horizontal field angle and vertical field angle) in the horizontal direction and vertical direction as specifications, and images (takes a shot of image of) an area within a rectangular or elliptical field angle range on each continuous plane in the inner (back) direction. (See FIGS. 3(A) to 3(C)). Some LIDARs have an elliptical field angle range. If there is a shielding object (not shown) between the imaging part 300 and the measurement object (not shown), the imaging part 300 measures a distance from the imaging part 300 to the shielding object and does not image the measurement object in the inner of the shielding object. The field angle range of the imaging part 300 becomes narrower as it approaches the imaging part 300. The imaging part 300 cannot image at a certain close distance (several tens cm to 1 m, depending on the model). In a case where the imaging part 300 is used in a narrow space inside the container 11 of a truck, there may be a case where only a narrow range can be imaged depending on the amount of baggage (see FIGS. 4(A) and 4(B)). In FIG. 4A, portions near the container 11 sides in the left and right of the imaging part 300 are occlusions (shielded areas), and the portions near the container 11 sides in the left and right as shown in FIGS. 5(A) and (C) becomes occlusions without a point group. In FIG. 4(B), the portion near the bottom surface of the container 11 becomes occlusion, and as FIGS. 5(B) and 5(C), the portion near the bottom surface of the container 11 becomes occlusion without a point group.

[0054]

A visualizable area that can be visualized by voxelization of the imaging data (point group) imaged by the imaging part 300 becomes as shown in FIG. 6. Valid voxels that can be validated by the voxelization part (222 in FIG. 2) are within the visualizable area, and invalid voxels that are not validated are outside the visualizable area. Although the example in FIG. 6 is specialized for the vertical field angle, the horizontal field angle is also taken into consideration for processing.

The visualizable area in FIG. 6 is within the monitoring area designated by the monitoring area designation part (221 in FIG. 2). Such a visualizable area can be calculated from elements of the mounting position and swing angle (position relative to the monitoring area and the angle of the optical axis) of the imaging part 300, the imageable minimum distance specific to the imaging part 300 to be used, and field angle, and dead angles and non-imageable area in the voxel grid can also be calculated from the same elements.

[0055]

FIG. 7 shows an example of changes in the visualization information of the baggage that can be visualized by the imaging part during the process of loading baggage in the container. Although the baggage at the inner (back) of the container, which are not affected by the field angle of the imaging part 300, can be estimated and interpolated from past data, the baggage is located closer to the front, the portions (corresponds to the non-visualizable package 20b in FIG. 7) that cannot be imaged becomes more, it becomes impossible to estimate and interpolate from past data, and a deviation from the actual load amount becomes large.

[0056]

Therefore, as shown in FIGS. 8 to 10, interpolation is performed to validate invalid voxels that satisfy predetermined conditions. In FIGS. 8 to 10, first, as shown in FIGS. 8(A), 9(A), and 10(A), the imaging part 300 images the baggage 20 in the container 11, and the point group as shown in FIGS. 8(B), 9(B), and FIG. 10(B) acquires from the imaged imaging data. Next, array data in the voxels at the position where the point group is present are validated into valid voxels is created, and projection array data obtained by projecting the voxels of the created array data from the front side to the inner (back) direction as shown in FIGS. 8(C), 9(C), and FIG. 10(C) is created. Next, in the projection array data, the invalid voxels on the same plane as the valid voxels marked with "★" (including each "×" in FIG. 10(C)) directly above the invalid voxels that are dead angles are validated as shown in FIGS. 8(D),

9(D), and 10(D). However, if there is a valid voxel in the front of the voxel in the backward direction of the valid voxel in the inner as shown in FIGS. 9(C) and 9(D), the invalid voxel in the backward direction of the valid voxel in the inner is not validated at this stage, and the invalid voxel in the backward direction of the frontmost valid voxel is validated. In addition, how much the front direction of the invalid voxels in the dead angle should be validated is determined by confirming the chronological (time-series) data on the plane of the loading progress direction and from the progress increment in the front direction per unit time, and so on.

[0057]

In summary, the range that cannot be imaged is grasped from the field angle in the specifications of the imaging part 300, and invalid voxels that satisfy predetermined conditions are validated (interpolated). When a portion (the portion where the point group can be acquired) with the baggage in the past data disappears and the point group does not exist on the inner (back) side in the direction away from the imaging part 300, the baggage is determined to be placed on the front side that cannot be imaged. Also, it is determined that a baggage is not floating in the air (the point group is acquired above), or that the baggage exists in the downward direction of the part where the baggage is determined to be placed. It is necessary to relate the top, bottom, left, and right of the imaging part 300 respectively with the top, bottom, left, and right of the real world. Further, from the viewpoint of baggage collapse prevention, baggage is normally loaded from the left or right wall side, so if there is one or more baggage in the central part, it is determined that there are also baggage in the left or right direction thereof.

[0058]

Operations of the loading volume ratio measurement apparatus in the loading volume ratio measurement system according to the first embodiment will be described using the drawings. FIG. 11 is a flow chart diagram schematically showing operations of the loading volume ratio measurement apparatus in the loading volume ratio measurement

system according to the first embodiment. Please see FIGS. 1 and 2 about the configuration parts of the loading volume ratio measurement system and the loading volume ratio measurement apparatus.

[0059]

5 First, the operation part 241 of the interface part 240 of the loading volume ratio measurement apparatus 200 sets parameters by the user's operation (step A1). In setting the parameters, the monitoring area is designated to the monitoring area designation part 221, the voxel side length is designated to the voxelization part 222, the interval time  
10 for relating to the array data 111 is designated to the array processing part 223, the monitoring area and the voxel side length are designated to the field angle occlusion voxel calculation part 225, the warning value (loading volume ratio, change in baggage height) are designated to the warning value designation part 231, and the like. In the  
15 designation of the monitoring area, the entire area that needs to be measured, for example, in accordance with the inner dimensions of the container, is designated. Also, the designations of the monitor region and the voxel side length to the field angle occlusion voxel calculation part 225 is the same as the designations of the monitor region and the  
20 voxel side length to the monitor region designator 221 and the voxelization part 222.

[0060]

After step A1 or when the loading volume ratio has changed (YES in step A12), the format conversion part 211 of the preprocessing part  
25 210 of the loading volume ratio measurement apparatus 200 sequentially acquires the imaging data 100 (3-dimensional point group) from the imaging part 300 (step A2). Here, it is assumed that the imaging part 300 is imaging the entire area inside the container 11 of the truck 10.

[0061]

30 Next, the format conversion part 211 converts the format of the imaging data 100 into a common format that can be commonly used in the loading volume ratio measurement apparatus 200 (step A3).

[0062]

Next, the noise removal part 212 of the preprocessing part 210 of the loading volume ratio measurement apparatus 200 removes noise (point groups unnecessary for measurement) from the point groups in the imaging data 100 from the format conversion part 211 (step A4).

5 [0063]

Next, the monitoring area designation part 221 of the loading volume management part 220 of the loading volume ratio measurement apparatus 200 acquires the point group existing in the monitoring area designated by the operation part 241 among the imaging data 100 from the noise removal part 212 (step A5).

10 [0064]

Next, the voxelization part 222 of the loading volume management part 220 of the loading volume ratio measurement apparatus 200 creates array data 111 by voxelizing the point group within the monitoring area of the imaging data 100 acquired by the monitoring area designation part 221 (step A6). Here, in creating the array data 111, a virtual voxel grid is created by dividing the monitoring area by voxels having a voxel side length designated by the operation part 241, and the array data 111 can be created so that voxels having a point group in which a number of points exist a predetermined number or more in the monitoring area of the data 100 are validated into valid voxels, and voxels having a point group in which a number of points exist less than the predetermined number in the monitoring area of the data 100 are invalidated into invalid voxels, among the voxels in the created voxel grid.

25 [0065]

Next, the field angle occlusion voxel calculation part 225 of the loading volume ratio measurement apparatus 200 calculates dead angle invalid voxel position information (position information of invalid voxels that cannot be visualized in the occlusion portion that is the dead angle of the imaging part 300) (step A7). Here, in calculating the dead angle invalid voxel position information, based on the monitoring area and the voxel side length designated by the operation part 241 and the

imaging part specification data 113 (the imaging part mounting position information and the field angle information) acquired from the imaging part specification data storage part 226, the position information of the dead angle invalid voxel in the voxel grid divided by the voxels of the voxel side length in the management area is calculated.

[0066]

Next, the array processing part 223 of the loading volume management part 220 of the loading volume ratio measurement apparatus 200 creates load array data 112 interpolated so that invalid voxels of occlusion portions (including dead angles, portions of shadows of objects and the like) satisfying a predetermined condition are validated into valid voxels, based on the multiple time-series array data 111 from the voxelization part 222 and the dead angle invalid voxel position information from the field angle occlusion voxel calculation part 225 (step A8). Details of step A7[sic., 8] will be described later.

[0067]

Here, the creating the loading array data 112 comprises: creating the array data group 110, relating to the array data 111 from the voxelization part 222 at each interval time designated by the operation part 241 so as to arrange chronologically the array data 111 in the interval time; storing the created array data group 110 in the array data group storage part 224; creating estimated array data obtained by estimating valid voxels in a state where an occlusion portion is excluded by comparing each array data 111 of the stored array data group 110 for each array data group 110; and creating the loading array data 112 by validating (interpolating) invalid voxels (including dead angle invalid voxels) in the direct downward direction thereof, in the left or right direction, and in the inner (back) direction based on the valid voxels of the created estimated array data,

[0068]

Next, the loading volume ratio calculation part 232 of the result generation part 230 of the loading volume ratio measurement apparatus 200 calculates a loading volume ratio based on the loading array data

112 from the array processing part 223 of the loading volume management part 220 (step A9). When calculating the loading volume ratio, it is determined whether or not the calculated loading volume ratio is a warning value designated by the warning value designation part 231 or more.

[0069]

Next, the voxel visualization part 233 of the result generation part 230 of the loading volume ratio measurement apparatus 200 creates visualization information by visualizing valid voxels based on the loading array data 112 from the array processing part 223 of the loading volume management part 220 (step A10). When creating the visualization information, it is determined whether or not there is a change in height of the warning value designated by the warning value designation part 231 or more in the created visualization information. Here, in creating the visualization information, grid lines can be drawn on the image of the loading array data 112. Step A10 may be performed simultaneously with step A9 or may be performed prior to step A9.

[0070]

Next, the display part 242 of the interface part 240 of the loading volume ratio measurement apparatus 200 displays the loading volume ratio from the loading volume ratio calculation part 232 (warning display information when the determination result indicates a change in height of the warning value or more) and the visualization information from the voxel visualization part 233 (warning display information when the determination result indicates a change in height of the warning value or more) is displayed (step A11). The displayed value of loading volume ratio is stored in the loading volume ratio measurement apparatus 200.

[0071]

Next, the loading volume ratio measurement apparatus 200 determines whether or not the value of the loading volume ratio displayed this time has changed from the value of the loading volume ratio displayed last time (step A12). A change in the value of the loading

volume ratio can be regarded as no change when there is no change for a predetermined number of times (for example, three times). When there is a change in the value of the loading volume ratio (YES in step A12), the process returns to step A2. When there is no change in the value of the loading volume ratio (NO in step A12), the process ends.

[0072]

Next, detailed operations of step A7[sic., 8] of the loading volume ratio measurement apparatus in the loading volume ratio measurement system according to the first embodiment will be described with reference to the drawings. FIG. 12 is a flow chart schematically showing the detailed operations of step A7[sic., 8] in FIG. 11 of the loading volume ratio measurement apparatus in the loading volume ratio measurement system according to the first embodiment.

[0073]

After calculating the invalid voxel position information in step A7, the array processing part 223 of the loading volume management part 220 of the loading volume ratio measurement apparatus 200 determines whether or not there is a valid voxel within the monitoring area in the plurality of time-series array data 111 from the voxelization part 222 (step B1). When no valid voxel exists within the monitoring area (NO in step B1), the process proceeds to step B9.

[0074]

When there is a valid voxel within the monitoring area (YES in step B1), the array processing part 223 creates estimated array data by estimating valid voxels excluding the occlusion portion where the obstacle in the front hides the measurement object in the back and makes it invisible based on the plurality of time-series array data 111 and the valid voxels in the created estimated array data are projected onto a two-dimensional plane (see, for example, FIG. 8(C), FIG. 9(C), FIG. 10(C)) (step B2).

[0075]

After step B2, the array processing part 223 determines whether or not the entire area of the projected two-dimensional plane is valid

voxels (step B3). When the entire area of the two-dimensional plane is valid voxels (YES in step B3), the process proceeds to step B8.

[0076]

When a portion of the two-dimensional plane is not valid voxels (NO in step B3), the array processing part 223 reads and refers to the past data of the array data group 110 from the array data group storage part 224 (step B4).

[0077]

After step B4, the array processing part 223 determines whether or not there is a dead angle invalid voxel on the same plane as the frontmost valid voxel of three-dimensional voxel in the current array data 111 within a predetermined distance from the frontmost valid voxel in the past data by using the dead angle invalid voxel position information calculated in step A7 (step B5). When there is no dead angle invalid voxel within the predetermined distance from the frontmost valid voxel in the past data (NO in step B5), the process proceeds to step B8.

[0078]

When there is a dead angle invalid voxel within the predetermined distance from the frontmost valid voxel in the past data (YES in step B5), the array processing part 223 validates all of dead angle invalid voxels existing in the left or right direction of the frontmost valid voxel of the three-dimensional voxel in the current array data 111 to valid voxels (step B6).

[0079]

After step B6, the array processing part 223 validates all of dead angle invalid voxels in the backward direction of the frontmost valid voxel (including the valid voxel validated in step B6) of the three-dimensional voxels in the current array data 111 to valid voxels (step B7).

[0080]

In a case where the entire area is valid voxels (YES in step B3), in a case where there is no dead angle invalid voxel within the

predetermined distance from the frontmost valid voxel in the past data (NO in step B5), or after step B7, the array processing part 223 validates all of invalid voxels in the inner direction of the frontmost valid voxel (including the valid voxels validated in steps B6 and B7) of the three-dimensional voxels in the current array data 111 to valid voxels (step B8), and then the process proceeds to step A9 in FIG. 11.

[0081]

In a case where no valid voxel exists within the monitoring area (NO in step B1), the array processing part 223 determines whether or not there is a valid voxel outside the monitoring area in the plurality of time-series array data 111 from the voxelization part 222 (step B9).

[0082]

In a case where there is a valid voxel outside the monitoring area (YES in step B9), or in a case where no baggage is loaded (NO in step B12), the array processing part 223 determines that no baggage is loaded within the monitoring area. (Step B10), and then the process proceeds to step A9 in FIG. 11.

[0083]

In a case where there is no valid voxel outside the monitoring area (NO in step B9), the array processing part 223 reads and refers to the past data of the array data group 110 from the array data group storage part 224 (step B11).

[0084]

After step B11, the array processing part 223 determines whether or not baggage is loaded within the monitoring area in the past data in the array data group 110 (step B12). When no baggage is loaded (NO in step B12), the process proceeds to step B10.

[0085]

In a case where baggage is loaded (YES in step B12), the array processing part 223 validates the invalid voxels of the three-dimensional voxels in the current array data 111, the invalid voxels corresponding to valid voxels in the past data (step B13).

[0086]

After step B13, the array processing part 223 determines whether or not a state in which no valid voxel exists has continued for a predetermined time or longer by referring to past data (step B14).

[0087]

5 In a case where the state in which no valid voxel exists has continued for the predetermined time or longer (YES in step B14), the array processing part 223 determines that the entire monitoring area has been loaded (step B15), and then the process proceeds to step A9 in FIG. 11.

10 [0088]

In a case where the state in which no valid voxel exists has not continued for the predetermined time or longer (NO in step B14), the array processing part 223 determines that there is a possibility that a baggage is being loaded (i.e., is under loading) onto the monitoring area (step B16), and then the process proceeds to step A9 in FIG. 11.

15 [0089]

According to the first embodiment, by voxelizing the point group of the monitoring area of the imaging data 100 imaged by the imaging part 300; validating all of dead angle invalid voxels in the left or right direction or the downward direction of the frontmost valid voxels in the monitoring area; and validating all of invalid voxels in the inner (back) direction to calculate the loading volume ratio, even if there is a baggage at a close distance from the imaging part, it is possible to contribute to suppressing a divergence between the measured load amount and the actual load amount of the baggage on a volume basis without using a multiple of imaging parts. This makes it possible to contribute to accurately recognizing a situation of the entire baggage while automatically monitoring the loading volume ratio. In addition, occlusion caused by the specifications of the imaging part 300 can be removed, and it can be applied even when a plurality of imaging parts 300 are mounted and a dead angle occurs. Even if the imaging part 300 is mounted close to the truck or mounted in the container, it is possible to visualize the loading more appropriately, so that the flexibility

(flexibility, versatility) of the installation location of the imaging part 300 is increased.

[0090]

Also, according to the first embodiment, it is possible to visualize the loading volume and the loading volume ratio of the baggage 20 that is sequentially loaded from the inner (back) of the container 11 toward the front, or conversely, the baggage 20 that are sequentially unloaded from the front quantitatively. As a result, it is possible to provide data that is easy for the observer to determine in real-time without depending on the individual determination of the person who loads the baggage 20.

[0091]

Further, according to the first embodiment, by analyzing the imaging data 100 chronologically, it is possible to reduce an influence that might be by temporary occlusion factors, such as a person during work, caused by using only one imaging part 300.

[0092]

Furthermore, according to the first embodiment, by voxelizing the point group of the monitoring area of the imaging data 100 (converting the data into an array of voxels obtained by dividing the data into unit grids at any time), the amount of calculation can be reduced; interpolation processing for sparse data and estimation processing for missing portions due to occlusion can be simplified; and high-speed computation can be performed.

[0093]

[Second embodiment]

A loading volume ratio measurement apparatus according to a second embodiment will be described with reference to the drawings. FIG. 13 is a block diagram schematically showing configurations of the loading volume ratio measurement apparatus according to the second embodiment.

[0094]

The loading volume ratio measurement apparatus 200 is an apparatus that measures a loading volume ratio of a measurement object

within a monitoring area. The loading volume ratio measurement apparatus 200 comprises a monitoring area designation part 221, a voxelization part 222, a field angle occlusion voxel calculation part 225 and an array processing part 223.

5 [0095]

The monitoring area designation part 221 is configured to acquire a point group existing in a monitoring area in which an area in which a measurement object(s) is loaded is designated in a predetermined space among imaging data 100 obtained by imaging the predetermined space  
10 by using an imaging part (not shown).

[0096]

The voxelization part 222 is configured to create array data 111 obtained by validating a voxel(s) in which a number of points of the point group exist at a predetermined number or more into (as) a valid  
15 voxel(s) among voxels in voxel grids obtained by dividing the monitoring area by voxels having a voxel side length designated in advance.

[0097]

The field angle occlusion voxel calculation part 225 is configured  
20 to calculate a dead angle invalid voxel position information 114 related to a position of the dead angle invalid voxel(s) that cannot be visualized in an occlusion portion that is a dead angle of the imaging part in the voxel grids within the array data 111, based on imaging part mounting position information related to a position at which the imaging part is  
25 mounted, field angle information related to a field angle of the imaging part, the monitoring area, and the voxel side length.

[0098]

The array processing part 223 is configured to create estimated array data obtained by estimating a valid voxel(s) in a state excluding  
30 an occlusion portion in which an obstacle(s) in the front hides a measurement object(s) in the back of the obstacle(s) and makes the measurement object(s) invisible, based on a plurality of array data 111 within a prespecified interval time. The array processing part 223 is

configured to create loading array data 112 obtained by validating all of the dead angle invalid voxel(s) in the left or right direction or downward direction of the frontmost valid voxel(s) in the estimated array data into (as) a valid voxel(s) and validating all of the invalid voxel(s) in a back direction of all of the valid voxel(s) after validation into a valid voxel(s) when satisfying a predetermined condition.

[0099]

The loading volume ratio calculation part 232 is configured to calculate a loading volume ratio which is a ratio of a volume of the measurement object loaded in the monitoring area relative to a total volume in the monitoring area based on the loading array data 112.

[0100]

According to the second embodiment, by voxelizing the point group of the monitoring area of the imaging data 100 imaged by the imaging part; validating all of dead angle invalid voxels in the left or right direction or the downward direction of the frontmost valid voxel(s) in the monitoring area when satisfying the predetermined condition; and validating all of invalid voxels in the inner direction to calculate the loading volume ratio, even if there is a baggage at a close distance from the imaging part, it is possible to contribute to suppressing a divergence between the measured load amount and the actual load amount of the baggage on a volume basis without using a multiple of imaging parts.

[0101]

It should be noted that the loading volume ratio measurement apparatus according to the first and second embodiments can be configured by so-called hardware resources (information processing apparatus, computer), and can use one comprising a configuration exemplarily shown in FIG. 14. For example, the hardware resources 1000 comprises a processor 1001, a memory 1002, a network interface 1003, etc., which are interconnected by internal bus 1004.

[0102]

It should be noted that the configuration shown in FIG. 14 is not intended to limit a hardware configuration of the hardware resources

1000. The hardware resources 1000 may comprise a hardware not shown (for example, an input/output interface). Alternatively, it is not intended to limit the number of units such as the processors 1001 included in the apparatus to the example shown in FIG. 14 as well. For example, multiple processors 1001 may be included in the hardware resource 1000. As the processor 1001, for example, a CPU (Central Processing Unit), MPU (Micro Processor Unit), GPU (Graphics Processing Unit), or the like can be used.

[0103]

As the memory 1002, for example, RAM (Random Access Memory), ROM (Read Only Memory), HDD (Hard Disk Drive), SSD (Solid State Drive), etc. can be used.

[0104]

As the network interface 1003, for example, a LAN (Local Area Network) card, network adapter, network interface card, etc. can be used.

[0105]

The functions of the hardware resources 1000 are realized by the above processing modules. The processing module is realized by the processor 1001 executing a program stored in the memory 1002, for example. Also, the program can be downloaded via a network or updated using a storage medium storing the program. Further, the functions performed by the above processing module may be realized by a semiconductor chip. In other words, the functions performed by the above processing module may be realized by executing software in some kind of hardware.

[0106]

Part or all of the above embodiments can be described as the following MODES but are not limited to the following.

[0107]

[MODE 1]

A loading volume ratio measurement apparatus, comprising:  
a monitoring area designation part configured to acquire a point group existing in a monitoring area in which an area in which a measurement

object(s) is loaded is designated in a predetermined space among imaging data obtained by imaging the predetermined space using an imaging part;

a voxelization part configured to create array data obtained by validating a voxel(s) in which a number of points of the point group exist at a predetermined number or more into (as) a valid voxel(s) among voxels in voxel grids obtained by dividing the monitoring area by a voxel having a voxel side length designated in advance;

a field angle occlusion voxel calculation part configured to calculate a dead angle invalid voxel position information related to a position of the dead angle invalid voxel(s) that cannot be visualized in an occlusion portion that is a dead angle of the imaging part in the voxel grids within the array data, based on imaging part mounting position information related to a position where the imaging part is mounted, field angle information related to a field angle of the imaging part, the monitoring area, and the voxel side length;

an array processing part configured to create estimated array data obtained by estimating a valid voxel(s) in a state excluding an occlusion portion in which an obstacle(s) in the front hides a measurement object(s) in the back of the obstacle(s) and makes the measurement object(s) invisible, based on the plurality of array data within a prespecified interval time, and when satisfying a predetermined condition, creating loading array data obtained by validating all of the dead angle invalid voxel(s) in the left or right direction or downward direction of the frontmost valid voxel(s) in the estimated array data into (as) a valid voxel(s) and validating all of the invalid voxel(s) in a back direction of all of the valid voxel(s) after validation into a valid voxel(s); and

a loading volume ratio calculation part configured to calculate a loading volume ratio which is a ratio of a volume of the measurement object loaded in the monitoring area relative to a total volume in the monitoring area based on the loading array data.

[MODE 2]

The loading volume ratio measurement apparatus according to MODE 1, wherein the array processing part is configured to create the estimated array data when a valid voxel(s) exists in the monitoring area in the plurality of array data.

5 [MODE 3]

The loading volume ratio measurement apparatus according to MODE 1 or 2, wherein the array processing part is configured to project the valid voxel(s) in the estimated array data onto a two-dimensional plane, and, as the predetermined condition, when the valid voxel(s) does not exist  
10 in a portion of the two-dimensional plane, invalidate all of the dead angle invalid voxel(s) in the left or right direction or downward direction of the frontmost valid voxel in the estimated array data into (as) a valid voxel(s).

[MODE 4]

15 The loading volume ratio measurement apparatus according to any one of MODES 1 to 3, wherein when creating the loading array data, the array processing part is configured to validate all of the dead angle invalid voxel(s) in the left or right direction of the frontmost valid voxel(s) in the estimated array data into (as) a valid voxel(s), as the  
20 predetermined condition, when the dead angle invalid voxel(s) exists within a predetermined distance from a position of the frontmost valid voxel(s) in the past data, and validate all of the dead angle invalid voxel(s) in the downward direction of the frontmost valid voxel(s) after validation into a valid voxel(s).

25 [MODE 5]

The loading volume ratio measurement apparatus according to MODE 4, wherein after validating all of the dead angle invalid voxels in the downward direction into a valid voxel(s), the array processing part is configured to validate all of the invalid voxel(s) in the inner direction  
30 of all of the valid voxel(s) after validation into a valid voxel(s).

[MODE 6]

The loading volume ratio measurement apparatus according to any one of MODES 1 to 5, wherein when creating the loading array data, the

array processing part is configured to create a loading array data in which all of the invalid voxel(s) in the inner direction of all of the valid voxel(s) are validated into a valid voxel(s), as the predetermined condition, when the dead angle invalid voxel(s) does not exist within the predetermined distance from the position of the frontmost valid voxel(s) in the past data.

[MODE 7]

The loading volume ratio measurement apparatus according to MODE 3, wherein the array processing part is configured to create loading array data obtained by validating all of the invalid voxel(s) in the inner direction of all of the valid voxel(s) into a valid voxel(s), as the predetermined condition, when the valid voxel(s) exists in an entire area of the two-dimensional plane.

[MODE 8]

A loading volume ratio measurement system, comprising:  
an imaging part configured to output imaging data obtained by imaging a predetermined space; and  
a loading volume ratio measurement apparatus according to any one of MODES 1 to 7.

[MODE 9]

A loading volume ratio measurement method of measuring a loading volume ratio using a hardware resource(s), comprising:  
acquiring a point group existing in a monitoring area in which an area in which a measurement object(s) is loaded is designated in a predetermined space among imaging data obtained by imaging the predetermined space using an imaging part;  
creating array data obtained by using a voxel(s) in which a number of points of the point group exist at a predetermined number or more into (as) a valid voxel(s) among voxels in voxel grids obtained by dividing the monitoring area by a voxel having a voxel side length designated in advance;  
calculating a dead angle invalid voxel position information related to a position of the dead angle invalid voxel(s) that cannot be visualized in

an occlusion portion that is a dead angle of the imaging part in the voxel grids within the array data, based on imaging part mounting position information related to a position where the imaging part is mounted, field angle information related to a field angle of the imaging part, the monitoring area, and the voxel side length;  
5 creating estimated array data obtained by estimating a valid voxel(s) in a state excluding an occlusion portion in which an obstacle(s) in the front hides a measurement object(s) in the back of the obstacle(s) and makes the measurement object(s) invisible, based on the plurality of  
10 array data within a prespecified interval time, and when satisfying a predetermined condition, creating loading array data obtained by validating all of the dead angle invalid voxel(s) in the left or right direction or downward direction of the frontmost valid voxel(s) in the estimated array data into (as) a valid voxel(s) and validating all of the  
15 invalid voxel(s) in a back direction of all of the valid voxel(s) after validation into a valid voxel(s); and  
calculating a loading volume ratio which is a ratio of a volume of the measurement object loaded in the monitoring area relative to a total volume in the monitoring area based on the loading array data.

20 [MODE 10]

A program causing a hardware resource(s) to execute measuring a loading volume ratio, wherein the program causes a hardware resource(s) to execute:

25 acquiring a point group existing in a monitoring area in which an area in which a measurement object(s) is loaded is designated in a predetermined space among imaging data obtained by imaging the predetermined space using an imaging part;  
creating array data obtained by using a voxel(s) in which a number of points of the point group exist at a predetermined number or more into  
30 (as) a valid voxel(s) among voxels in voxel grids obtained by dividing the monitoring area by a voxel having a voxel side length designated in advance;  
calculating a dead angle invalid voxel position information related to a

position of the dead angle invalid voxel(s) that cannot be visualized in an occlusion portion that is a dead angle of the imaging part in the voxel grids within the array data, based on imaging part mounting position information related to a position where the imaging part is mounted, field angle information related to a field angle of the imaging part, the monitoring area, and the voxel side length;

creating estimated array data obtained by estimating a valid voxel(s) in a state excluding an occlusion portion in which an obstacle(s) in the front hides a measurement object(s) in the back of the obstacle(s) and makes the measurement object(s) invisible, based on the plurality of array data within a prespecified interval time, and when satisfying a predetermined condition, creating loading array data obtained by validating all of the dead angle invalid voxel(s) in the left or right direction or downward direction of the frontmost valid voxel(s) in the estimated array data into (as) a valid voxel(s) and validating all of the invalid voxel(s) in a back direction of all of the valid voxel(s) after validation into a valid voxel(s); and

calculating a loading volume ratio which is a ratio of a volume of the measurement object loaded in the monitoring area relative to a total volume in the monitoring area based on the loading array data.

[0108]

It should be noted that each disclosure of the above PTLs is incorporated herein by reference and can be used as the basis or part of the present invention as necessary. Within the framework of the entire disclosure of the present invention (including claims and drawings), modifications and adjustments of the embodiments or examples are possible based on the basic technical concept thereof further. Also, various combinations or selections (if necessary, not selection) of various disclosure elements (including each element of each claim, each element of each embodiment or example, each element of each drawing, etc.) within the framework of the entire disclosure of the present invention is possible. That is, the present invention naturally includes various variations and modifications that can be made by one skilled in

the art according to the entire disclosure including the claims and drawings, and the technical idea. Further, with regard to numerical values and numerical ranges described in the present application, it is assumed that any intermediate values, sub-numerical values and sub-ranges thereof are described even if not specified. Furthermore, it is assumed that each disclosure matter of the above-cited document, and the matter using a part or all of the present invention as a part of the disclosure of the present invention in accordance with the meaning of the present invention if necessary in combination with the matters described in the present document are included in (belong to) the disclosure matter of the present application.

#### REFERENCE SIGNS LIST

[0109]

- 1 Loading volume ratio measurement system
- 10 Truck
- 11 Truck container
- 20 Baggage
- 20a Visualizable baggage
- 20b Non-visualizable baggage
- 100 Imaging data
- 110 Array data group
- 111 Array data
- 112 Loading array data
- 113 Imaging part specification data
- 114 Dead angle invalid voxel position information
- 200 Loading volume ratio measurement apparatus
- 210 Preprocessing part
- 211 Format conversion part
- 212 Noise removal part
- 220 Loading volume management part
- 221 Monitoring area designation part
- 222 Voxelization part
- 223 Array processing part

- 224 Array data group storage part
- 225 Field angle occlusion voxel calculation part
- 226 Imaging part specification data storage part
- 230 Result generation part
- 5 231 Warning value designation part
- 232 Loading volume ratio calculation part
- 233 Voxel visualization part
- 240 Interface part
- 241 Operation part
- 10 242 Display part
- 300 Imaging part
- 400 Network
- 1000 Hardware resource(s)
- 1001 Processor
- 15 1002 Memory
- 1003 Network interface
- 1004 Internal bus

## CLAIMS:

1. A loading volume ratio measurement apparatus, comprising:

a monitoring area designation part configured to acquire a point group existing in a monitoring area in which an area in which a measurement object(s) is loaded is designated in a predetermined space among imaging data obtained by imaging the predetermined space using an imaging part;

a voxelization part configured to create array data obtained by validating a voxel(s) in which a number of points of the point group exist at a predetermined number or more into a valid voxel(s) among voxels in voxel grids obtained by dividing the monitoring area by a voxel having a voxel side length designated in advance;

a field angle occlusion voxel calculation part configured to calculate a dead angle invalid voxel position information related to a position of the dead angle invalid voxel(s) that cannot be visualized in an occlusion portion that is a dead angle of the imaging part in the voxel grids within the array data, based on imaging part mounting position information related to a position where the imaging part is mounted, field angle information related to a field angle of the imaging part, the monitoring area, and the voxel side length;

an array processing part configured to create estimated array data obtained by estimating a valid voxel(s) in a state excluding an occlusion portion in which an obstacle(s) in the front hides a measurement object(s) in the back of the obstacle(s) and makes the measurement object(s) invisible, based on the plurality of array data within a prespecified interval time, and when satisfying a predetermined condition, creating loading array data obtained by validating all of the dead angle invalid voxel(s) in the left or right direction or downward direction of the frontmost valid voxel(s) in the estimated array data into a valid voxel(s) and validating all of the invalid voxel(s) in a back direction of all of the valid voxel(s) after validation into a valid voxel(s); and

a loading volume ratio calculation part configured to calculate a

loading volume ratio which is a ratio of a volume of the measurement object loaded in the monitoring area relative to a total volume in the monitoring area based on the loading array data.

2. The loading volume ratio measurement apparatus according to claim 1, wherein the array processing part is configured to create the estimated array data when a valid voxel(s) exists in the monitoring area in the plurality of array data.

3. The loading volume ratio measurement apparatus according to claim 1 or 2, wherein the array processing part is configured to project the valid voxel(s) in the estimated array data onto a two-dimensional plane, and, as the predetermined condition, when the valid voxel(s) does not exist in a portion of the two-dimensional plane, invalidate all of the dead angle invalid voxel(s) in the left or right direction or downward direction of the frontmost valid voxel in the estimated array data into (as) a valid voxel(s).

4. The loading volume ratio measurement apparatus according to any one of claims 1 to 3, wherein when creating the loading array data, the array processing part is configured to validate all of the dead angle invalid voxel(s) in the left or right direction of the frontmost valid voxel(s) in the estimated array data into (as) a valid voxel(s), as the predetermined condition, when the dead angle invalid voxel(s) exists within a predetermined distance from a position of the frontmost valid voxel(s) in the past data, and validate all of the dead angle invalid voxel(s) in the downward direction of the frontmost valid voxel(s) after validation into a valid voxel(s).

5. The loading volume ratio measurement apparatus according to claim 4, wherein after validating all of the dead angle invalid voxels in the downward direction into a valid voxel(s), the array processing part is configured to validate all of the invalid voxel(s) in the inner direction of all of the valid voxel(s) after validation into a valid voxel(s).

6. The loading volume ratio measurement apparatus according to any one of claims 1 to 5, wherein when creating the loading array data, the array processing part is configured to create a loading array data in

which all of the invalid voxel(s) in the inner direction of all of the valid voxel(s) are validated into a valid voxel(s), as the predetermined condition, when the dead angle invalid voxel(s) does not exist within the predetermined distance from the position of the frontmost valid voxel(s) in the past data.

7. The loading volume ratio measurement apparatus according to claim 3, wherein the array processing part is configured to create loading array data obtained by validating all of the invalid voxel(s) in the inner direction of all of the valid voxel(s) into a valid voxel(s), as the predetermined condition, when the valid voxel(s) exists in an entire area of the two-dimensional plane.

8. A loading volume ratio measurement system, comprising:  
an imaging part configured to output imaging data obtained by imaging a predetermined space; and

a loading volume ratio measurement apparatus according to any one of claims 1 to 7.

9. A loading volume ratio measurement method of measuring a loading volume ratio using a hardware resource(s), comprising:

acquiring a point group existing in a monitoring area in which an area in which a measurement object(s) is loaded is designated in a predetermined space among imaging data obtained by imaging the predetermined space using an imaging part;

creating array data obtained by using a voxel(s) in which a number of points of the point group exist at a predetermined number or more into (as) a valid voxel(s) among voxels in voxel grids obtained by dividing the monitoring area by a voxel having a voxel side length designated in advance;

calculating a dead angle invalid voxel position information related to a position of the dead angle invalid voxel(s) that cannot be visualized in an occlusion portion that is a dead angle of the imaging part in the voxel grids within the array data, based on imaging part mounting position information related to a position where the imaging part is mounted, field angle information related to a field angle of the

imaging part, the monitoring area, and the voxel side length;

creating estimated array data obtained by estimating a valid voxel(s) in a state excluding an occlusion portion in which an obstacle(s) in the front hides a measurement object(s) in the back of the obstacle(s) and makes the measurement object(s) invisible, based on the plurality of array data within a prespecified interval time, and when satisfying a predetermined condition, creating loading array data obtained by validating all of the dead angle invalid voxel(s) in the left or right direction or downward direction of the frontmost valid voxel(s) in the estimated array data into a valid voxel(s) and validating all of the invalid voxel(s) in a back direction of all of the valid voxel(s) after validation into a valid voxel(s); and

calculating a loading volume ratio which is a ratio of a volume of the measurement object loaded in the monitoring area relative to a total volume in the monitoring area based on the loading array data.

10. A program causing a hardware resource(s) to execute measuring a loading volume ratio, wherein the program causes a hardware resource(s) to execute:

acquiring a point group existing in a monitoring area in which an area in which a measurement object(s) is loaded is designated in a predetermined space among imaging data obtained by imaging the predetermined space using an imaging part;

creating array data obtained by using a voxel(s) in which a number of points of the point group exist at a predetermined number or more into a valid voxel(s) among voxels in voxel grids obtained by dividing the monitoring area by a voxel having a voxel side length designated in advance;

calculating a dead angle invalid voxel position information related to a position of the dead angle invalid voxel(s) that cannot be visualized in an occlusion portion that is a dead angle of the imaging part in the voxel grids within the array data, based on imaging part mounting position information related to a position where the imaging part is mounted, field angle information related to a field angle of the

imaging part, the monitoring area, and the voxel side length;

creating estimated array data obtained by estimating a valid voxel(s) in a state excluding an occlusion portion in which an obstacle(s) in the front hides a measurement object(s) in the back of the obstacle(s) and makes the measurement object(s) invisible, based on the plurality of array data within a prespecified interval time, and when satisfying a predetermined condition, creating loading array data obtained by validating all of the dead angle invalid voxel(s) in the left or right direction or downward direction of the frontmost valid voxel(s) in the estimated array data into a valid voxel(s) and validating all of the invalid voxel(s) in a back direction of all of the valid voxel(s) after validation into a valid voxel(s); and

calculating a loading volume ratio which is a ratio of a volume of the measurement object loaded in the monitoring area relative to a total volume in the monitoring area based on the loading array data.