

Description

Title of Invention: FOREIGN BODY DETECTION SYSTEM AND METHOD

Technical Field

5 [0001] The present disclosure relates to a foreign object detection system and a foreign object detection method in a target area, for example, a parking lot. This application claims the benefit of priority to Japanese Patent Application No. 2019-094735 filed on May 20, 2019, and
10 contents thereof are incorporated herein.

Background Art

[0002] In a space in which a vehicle enters and stops, for example, a loading/unloading space of a mechanical
15 parking lot, before operations of opening and closing a door of an entry/exit and transporting a pallet carrying the vehicle are performed, it is required to confirm that there is no foreign object, such as a driver, an occupant, or a luggage other than the vehicle. Such operation of confirming
20 absence of a foreign object can be visually performed by the driver or an attendant at the facility, for example, but the confirmation may not be performed thoroughly due to carelessness or other reasons when relying only on manpower. To address this problem, in recent years, in order to
25 reliably confirm absence of a foreign object, there is a demand for a technology of automatically detecting a foreign object in a target area without relying only on manpower.

[0003] Further, when an autonomous driving technology that is currently being developed in various countries is put into practice on a full-scale basis, it is expected that automation is advanced not only in vehicle driving, but also in various operations performed around the vehicle, such as opening and closing of the door and transporting the pallet as described above. For example, there is expected a case in which, after driving the occupant to a destination by autonomous driving, the vehicle automatically moves to a nearby mechanical parking lot to be stored in a storage space. In this case, the vehicle moves under a state in which the occupant is absent, and stops in the loading/unloading space. At this time, operations of opening and closing of the door, and starting to move the pallet, for example, may be executed by the attendant visually confirming absence of a foreign object and providing input on an operation button. However, the operations become smoother when there is a mechanism in which the absence of a foreign object is automatically confirmed, and the operations are started.

[0004] Such a mechanism configured to detect a foreign object may be widely required not only in the mechanical parking lot, but also in locations in which some operation is performed around a stopped vehicle, for example, a power feeding facility for an electric vehicle. Further, a similar mechanism is widely applicable to situations in which it is desired to detect a foreign object around some object without

limiting to the vehicle.

[0005] As a technology for automatically detecting a foreign object in a target area, there are proposed various methods of taking images in the target area with the use of cameras or the like and detecting a foreign object captured in the image. Examples of technical literatures in which such a technology is described include, for example, the following Patent Literatures 1 to 6.

10 Citation List

Patent Literature

[0006] Patent Literature 1: JP 2016-3493 A

Patent Literature 2: JP 2015-55073 A

Patent Literature 3: JP 2014-80735 A

15 Patent Literature 4: JP H08-42184 A

Patent Literature 5: JP S62-194366 A

Patent Literature 6: JP 2012-158968 A

Summary of Invention

20 Technical Problem

[0007] In the technology for detecting a foreign object as described above, minimum accuracy is at least required in the detection, but in addition, it is important in terms of cost required for construction or maintenance, for example, to simplify a device configuration as much as possible. However, the technology as described in any of the above-mentioned Patent Literatures 1 to 6 has not necessarily

reached to a point of sufficiently satisfying both accuracy and cost.

[0008] In view of the above, in the present disclosure, there is described a foreign object detection system and
5 method that can detect a foreign object with high accuracy with a configuration that is as simple as possible.

Solution to Problem

[0009] According to one embodiment of the present
10 disclosure, there is provided a foreign object detection system including: an image pickup device configured to take an image in a target area; an image processing unit configured to store a program for detecting, with use of deep learning, an object in the image taken by the image pickup
15 device; and a boundary determination unit configured to determine a positional relationship between a transmissive portion through which an outside of the target area is visible from an inside of the target area, and an object around the transmissive portion, wherein the foreign object
20 detection system is configured to: mask an area occupied by the transmissive portion of the image taken by the image pickup device; and detect the object based on the masked image by the program using the deep learning.

[0010] In the above-mentioned foreign object detection
25 system, the masking may be configured to be performed in the image pickup device.

[0011] In the above-mentioned foreign object detection

system, the masking may be configured to be performed in the image processing unit.

[0012] In the above-mentioned foreign object detection system, the boundary determination unit may be an object sensor configured to detect presence or absence of an object in a boundary area between the target area and an external space.

[0013] In the above-mentioned foreign object detection system, the object sensor may be configured to detect an irradiation wave radiated along a plane formed by the transmissive portion.

[0014] In the above-mentioned foreign object detection system, the boundary determination unit may be configured to determine whether the object detected in the image taken by the image pickup device is inside or outside the target area, based on a positional relationship between a position of the object in the image taken by the image pickup device, and the area occupied by the transmissive portion in the image.

[0015] In the above-mentioned foreign object detection system, the target area may be a loading/unloading space of a mechanical parking lot.

[0016] Further, according to another embodiment of the present disclosure, there is provided a foreign object detection method including: an image taking step of taking an image in a target area; a masking step of masking an area occupied by a transmissive portion through which an outside of the target area is visible from an inside of the target

area in the image taken in the image taking step; a first object detection step of detecting an object based on the image on which the masking step has been performed, by a program using deep learning; and a second object detection
5 step of detecting presence or absence of an object in a boundary area of the target area.

[0017] Furthermore, according to still another embodiment of the present disclosure, there is provided a foreign object detection method including: an image taking
10 step of taking an image in a target area; an object detection step of detecting an object based on the image taken in the image taking step by a program using deep learning; and a position determination step of determining whether the object detected in the image is inside or outside the target area,
15 based on a positional relationship between a position of the object in the image, and an area occupied by a transmissive portion through which an outside of the target area is visible from an inside of the target area in the image.

[0018] In the above-mentioned foreign object detection
20 method, the target area may be a loading/unloading space of a mechanical parking lot.

[0019] According to the foreign object detection system and the method of the present invention, it is possible to provide an excellent effect that a foreign object is
25 detectable with high accuracy with a configuration that is as simple as possible.

Brief Description of Drawings

[0020] FIG. 1 is a schematic plan view for illustrating arrangement of devices in a foreign object detection system according to a first embodiment of the present disclosure.

5 FIG. 2 is a block diagram for illustrating a system configuration of the foreign object detection system according to the first embodiment of the present disclosure.

FIG. 3 is a view for illustrating an example of an image taken in the first embodiment of the present
10 disclosure.

FIG. 4 is a view for illustrating an example of an image which is taken and a part of which is subjected to masking in the first embodiment of the present disclosure.

FIG. 5 is a view for illustrating another example of an
15 image which is taken and a part of which is subjected to masking in the first embodiment of the present disclosure.

FIG. 6 is a flow chart for illustrating an example of a procedure of a foreign object detection method according to the first embodiment of the present disclosure.

20 FIG. 7 is a schematic plan view for illustrating arrangement of devices in a foreign object detection system according to a second embodiment of the present disclosure.

FIG. 8 is a block diagram for illustrating a system configuration of the foreign object detection system
25 according to the second embodiment of the present disclosure.

FIG. 9 is a view for illustrating an example of an image taken in the second embodiment of the present

disclosure.

FIG. 10 is a view for illustrating an example of an image which is taken and subjected to object detection processing by a program in the second embodiment of the present disclosure.

FIG. 11 is a flow chart for illustrating an example of a procedure of a foreign object detection method according to the second embodiment of the present disclosure.

10 Description of Embodiments

[0021] Now, embodiments of the present disclosure are described with reference to the accompanying drawings. In a foreign object detection system according to a first embodiment illustrated in FIG. 1, a loading/unloading space of a mechanical parking facility is assumed as a target area A. Further, when there is an object (foreign object F) other than a vehicle 1 in the target area A, the foreign object F is detected. The target area A as the loading/unloading space is a space surrounded by walls in four directions, and has provided on a front side thereof (lower side of FIG. 1) a loading/unloading port 4 serving as a transmissive portion, through which the vehicle 1 enters and exits.

[0022] The term "foreign object" as used herein refers to an object that is present in the target area and that is other than a target object (in this case, vehicle 1 serving as a target object of transport), and that is other than objects originally arranged in the target area and is

representatively a driver or an occupant of the vehicle, or an attendant at the facility. Further, a luggage carried in the target area A and placed outside the vehicle 1 is another example of the "foreign object." FIG. 1 shows two foreign
5 objects F inside the target area A as an example. FIG. 1 also shows one object O outside the target area A.

[0023] The term "transmissive portion" refers to an optical opening through which the outside of the target area is visible from the inside thereof. In other words, the
10 transmissive portion in the first embodiment is the loading/unloading port 4 that is in communication with an external space both optically and physically. In addition, a glass window through which light is transmitted, a portion that is fenced off from an adjacent space, or the like can
15 also be expected as a "transmissive portion."

[0024] A pallet 2 configured to transport the vehicle 1 enters or exits the target area A serving as the loading/unloading space from or into a storage space (not shown) outside the target area A. A standard position of the
20 pallet 2 in the target area A is a center portion of the target area A. At the time of loading, the vehicle 1 enters the target area A through the loading/unloading port 4, stops on the pallet 2, and is transported to and stored in the storage space together with the pallet 2. At the time of
25 unloading, the vehicle 1 is transported from the storage space into the target area A together with the pallet 2, and then exits to the outside of the target area A through the

loading/unloading port 4.

[0025] In the target area A, image pickup devices 5, for example, cameras configured to take images in the target area A, are arranged. In the case of the first embodiment, as the image pickup device 5, a total of two image pickup devices 5a and 5b are installed around a stop position of the vehicle 1 as illustrated in FIG. 1. The image pickup device 5a of the two image pickup devices 5 is installed on the front left side, and the image pickup device 5b is installed on the back right side as viewed from the stop position of the vehicle 1. The image pickup devices 5a and 5b are arranged diagonally on the front side and the back side across the stop position of the vehicle 1, respectively, as described above, and thus the images can be taken of the entire surroundings of the vehicle 1 in the target area A.

[0026] On an inner wall near the loading/unloading port 4 as the transmissive portion, an object sensor 6 serving as a boundary determination unit is provided. The term "boundary determination unit" as used herein refers to a device or unit configured to determine a positional relationship between the transmissive portion (loading/unloading port 4) that is the optical opening, and an object (foreign object F or object O) around the transmissive portion. In the first embodiment, the object sensor 6 serving as the boundary determination unit is installed near the loading/unloading port 4 to detect some object when the object is located on a boundary line between

the inside and the outside of the target area A defined by the loading/unloading port 4. In this manner, when the object sensor 6 is installed as the boundary determination unit, the device configuration can be simplified in embodying
5 the foreign object detection system.

[0027] The object sensor 6 is, for example, a transmissive photoelectric sensor. The object sensor 6 includes an irradiation portion 6a provided on one of a left side and a right side of the loading/unloading port 4, and a
10 light receiving portion 6b provided on the other of the left side and the right side, and is configured to radiate irradiation light serving as an irradiation wave along a plane formed by the loading/unloading port 4 from the irradiation portion 6a, and detect the irradiation light by
15 the light receiving portion 6b. When there is some object between the irradiation portion 6a and the light receiving portion 6b, an amount of irradiation light detected by the light receiving portion 6b is changed. In this manner, the object sensor 6 can detect an object that exists between the
20 irradiation portion 6a and the light receiving portion 6b.

[0028] The term "boundary area" as used herein refers to an area near the boundary between the target area defined by the transmissive portion, and the external space. More specifically, the term "boundary area" refers to an area in
25 the target area A where it becomes difficult to detect a foreign object of interest when an area corresponding to the transmissive portion in an image is masked in a foreign

object detection process which is described later. In the example illustrated in FIG. 1, the object sensor 6 is arranged to radiate the irradiation wave along the boundary line defined by the loading/unloading port 4. Alternatively, 5 or additionally, however, the object sensor 6 may be configured to detect a foreign object F in a boundary area that is located more inward of the target area A. This is to more reliably prevent under-detection caused by the masking (such arrangement of the object sensor 6 is to be described again later). As the object sensor 6, other than the 10 transmissive photoelectric sensor, any device capable of detecting presence or absence of an object in a particular area may be used accordingly. For example, a photoelectric sensor of a type other than the transmissive type may be 15 used, or an ultrasonic sensor or the like may be used.

[0029] On an outer wall near the loading/unloading port 4, an operation unit 7, a display unit 8, and an alarm unit 9 are provided. The operation unit 7 is an input device through which opening and closing of the loading/unloading 20 port 4, transport of the pallet 2, and other operations of the respective units are input. The display unit 8 is a display configured to display the images in the target area A taken by the image pickup devices 5, and other information as required. The alarm unit 9 is a device configured to issue 25 an alarm when some event to which personnel should be alerted happens in the target area A, or somewhere in the facility including the target area A. Examples of the "some event to

which personnel should be alerted" include a case in which, when the vehicle 1 is to be transported to the storage space outside the target area A, for example, a foreign object F other than the vehicle 1 is detected in the target area A.

5 As a content of the alarm, a suitable form may be selected as long as the personnel can be alerted, such as an alarm sound, lighting of a warning lamp, and display of a warning message.

[0030] The positions where the operation unit 7, the display unit 8, and the alarm unit 9 are installed are not
10 limited to the positions described here. For example, devices corresponding thereto may be provided in a control room (not shown) or the like, or some of those devices may be provided in different locations. Further, in this example, for convenience of description, the operation unit 7, the
15 display unit 8, and the alarm unit 9 are illustrated separately, but there may be provided a touch panel display having the functions of the operation unit 7 and the display unit 8 in an integrated manner, for example. Still further, the function of the alarm unit 9 may be performed also by the
20 display unit 8 (that is, information corresponding to an alarm may be displayed on the display unit 8). In addition, the operation unit 7, the display unit 8, and the alarm unit 9 may be changed accordingly depending on the layout of the target area A and other conditions.

25 [0031] FIG. 2 shows an example of a system configuration involved in control of the image pickup devices 5, the object sensor 6, the operation unit 7, the display unit 8, and the

alarm unit 9. The image pickup devices 5, the object sensor 6, the operation unit 7, and the alarm unit 9 are informationally connected to a controller 10 through a communication bus, for example, Ethernet (trademark). The controller 10 is a device configured to monitor the entire mechanical parking lot including the target area A as the loading/unloading space and operate the respective units, and is configured to control opening and closing of the loading/unloading port 4, transport of the pallet 2, and actuation of the image pickup devices 5 and the object sensor 6, for example.

[0032] Further, the display unit 8 is connected to the communication bus via an image processing unit 11. The image processing unit 11 is an information processing device configured to perform appropriate processing on the images of the target area A taken by the image pickup devices 5, and is also configured to transmit image data to the display unit 8 and cause the display unit 8 to display the images as required.

[0033] As image processing performed in the image processing unit 11, detection of a foreign object F (see FIG. 1) is particularly assumed in the first embodiment. In other words, in the image processing unit 11, the images of the target area A acquired by the image pickup devices 5 are analyzed to determine whether a person or other object exists in the images. When an object is detected from the images to be processed in the image processing unit 11, or an object is

detected in the boundary area of the target area A by the object sensor 6 described above, the controller 10 determines that a foreign object F has been detected, and issues an alarm via the alarm unit 9.

5 [0034] The image processing unit 11 stores therein a program P for detecting an object captured in the images. This program P is configured to detect objects of particular types by a deep learning method with the use of a multilayer neural network. As an algorithm for the deep learning, for
10 example, various algorithms such as regional-convolutional neural network (R-CNN), Fast R-CNN, Faster R-CNN, You Only Look Once (YOLO), and Single Shot Multibox Detector (SSD) can be used, but another appropriate algorithm may be used.

[0035] The program P is configured to identify the type
15 of the object captured in the images, and output a probability that the object corresponds to the type of object, coordinates of a center of gravity of the object, a width and a height of the object with the use of the above-mentioned algorithms. The first type of the foreign objects
20 F expected in the target area A as the loading/unloading space of the mechanical parking lot is a person, and hence the program P is required to be configured to be able to discriminate at least a person from the image. As other
25 objects that can enter the target area A together with the vehicle 1, various objects such as a pet and other animals, a bag, and a baby carriage are expected, and hence the program P may be adapted to be able to detect those objects in

addition to a person. It is also assumed that, when the type of the target area to which the foreign object detection system is applied is different, types of objects to be detected as the foreign objects are also different. The
5 program P may be configured to be able to detect, without limiting to a person, various objects expected depending on the type of the target area.

[0036] When the vehicle 1 is to be loaded, the driver or the occupant of the vehicle 1, or the attendant or other
10 personnel at the facility operates and instructs the operation unit 7 to start loading. The controller 10 opens the loading/unloading port 4 in response to the instruction. When the loading is started, the loading/unloading port 4 is opened under a state in which an empty pallet 2 is deployed
15 in the center portion, which is the standard position in the target area A.

[0037] After the loading/unloading port 4 is opened, the driver moves the vehicle 1 into the target area A, and stops the vehicle 1 on the pallet 2. After the stopping, the
20 driver and other occupants get off the car, and exit the target area A. After all of the driver and other personnel exit, the driver or other personnel visually checks the inside of the target area A to see whether there is no person, luggage, or other foreign object F in the target area
25 A. Thereafter, the driver or other personnel operates the operation unit 7 to input that the vehicle 1 has stopped on the pallet 2. The controller 10 closes the loading/unloading

port 4, and transports the pallet 2 carrying the vehicle 1 to the storage space outside the target area A.

[0038] When the vehicle 1 is to be unloaded, the driver or the occupant of the vehicle 1, or the attendant or other
5 personnel at the facility operates and instructs the operation unit 7 to start unloading. The controller 10 transports the corresponding pallet 2 into the target area A, and opens the loading/unloading port 4 in response to the instruction. After the loading/unloading port 4 is opened,
10 the driver gets on the vehicle 1 on the pallet 2, and moves to the outside of the target area A. After the vehicle 1 exits to the outside, the driver of the vehicle 1 or the attendant or other personnel operates the operation unit 7 again to input that the unloading is completed. The
15 controller 10 closes the loading/unloading port 4 in response to the instruction.

[0039] The series of operation has been described above taking as an example the case in which the driver drives the vehicle 1, but there may also be a case in which the vehicle
20 1 is a self-driving car. In this case, a part or all of the above-mentioned operation of the vehicle 1 is performed without intervention of the driver.

[0040] In the image processing unit 11 (see FIG. 2), foreign object detection is executed at an appropriate
25 timing. For example, at the time of loading, when the vehicle 1 stops on the pallet 2 and the driver inputs it to the operation unit 7, the foreign object detection is

performed. At this time, the driver visually confirms the absence of a foreign object F in the target area A.

Furthermore, the confirmation can be thoroughly conducted by automatically executing the foreign object detection

5 simultaneously with using the object sensor 6, the image pickup devices 5, and the image processing unit 11. In addition, the foreign object detection can be performed at any timing when it is considered that a status of the target area A should be checked, for example, when the instruction
10 to start unloading is input, when the completion of unloading is input and the loading/unloading port 4 is to be closed, or at normal times when no operation is performed.

[0041] When the foreign object detection is to be performed, the controller 10 actuates the image pickup
15 devices 5 to take images in the target area A. In the image processing unit 11, object detection processing is executed by the program P on the images taken by the image pickup devices 5. Further, the controller 10 actuates the object sensor 6 to check whether there is no object in the boundary
20 area in the target area A.

[0042] When, as a result of image processing, an object of a type expected to be a foreign object F (for example, person) is detected in at least one image of the taken images, the controller 10 actuates the alarm unit 9 to issue
25 an alarm. At the same time, operations of the pallet 2, the loading/unloading port 4, or other units are prohibited. Further, a message that the foreign object F has been

detected may be displayed on the display unit 8. Still further, also when an object is detected by the object sensor 6, the controller 10 performs similar operations.

[0043] As described above, in performing the foreign object detection with the use of the program P, when the object detection by the object sensor 6 is executed in combination therewith, accuracy of the foreign object detection can be increased. A detailed description is provided below.

[0044] When detecting a foreign object F in the target area A as illustrated in FIG. 1 based on the images of the target area A taken by the image pickup devices 5, it is important to avoid creating blind spots. Meanwhile, it is desirable to reduce the number of devices forming the system as much as possible, and in particular, it is desirable to reduce the number of image pickup devices 5 as much as possible, as far as the accuracy of the foreign object detection is ensured. When the image processing is to be performed by the program P using the deep learning as

described above, a considerable computing load is caused in the image processing unit 11. FIG. 2 shows the image processing unit 11 as one block, but in some real cases, for example, one information processing device may be necessary for each image pickup device 5. Accordingly, reducing the number of image pickup device 5 is very important in terms of cost when the foreign object detection is performed with the use of the deep learning in particular. The arrangement of

the two image pickup devices 5 illustrated in FIG. 1 is one idea for taking the images in the target area A with a small number of image pickup device 5 so as to avoid creating blind spots (here, the foreign object detection system including two image pickup devices 5 has been exemplified, but the two image pickup devices 5 are a minimum required number for avoiding blind spots, and is not intended to prohibit addition of further image pickup devices for the purpose of increasing the detection accuracy).

[0045] Further, in the foreign object detection, it is required to reduce both under-detection and over-detection as much as possible. When the image pickup devices 5 are arranged as illustrated in FIG. 1, the loading/unloading port 4 occupies a large portion of an angle of view in each image pickup device 5. As a result, in the image taken by the image pickup device 5b, for example, as illustrated in FIG. 3, the object O located on the outside of the target area A may be captured in the image through the loading/unloading port 4, which is the transmissive portion. When the object O is an object (here, person) of a type that is detectable by the program P, over-detection may be caused.

[0046] In order to prevent the over-detection, as illustrated in FIG. 4, for example, a method may be conceived of including masking an area corresponding to the transmissive portion (loading/unloading port 4) captured in the image, and then executing the foreign object detection by the program P. However, when this method is adopted, a

portion of a foreign object F near the loading/unloading port 4 is also masked. When a masked amount or position is at the extent described in FIG. 4, the masked foreign object F can be detected by the program P. However, when the position of the foreign object F is even closer to the outside, most of the foreign object F may be masked as illustrated in FIG. 5 in some cases. In the example illustrated in FIG. 5, the foreign object F near the loading/unloading port 4 is located inside the target area A, but may not be detectable by the program P because of being mostly masked by the masking. To address this problem, the object sensor 6 arranged as illustrated in FIG. 1 is actuated to reliably detect the foreign object F in the boundary area, which may not be detected by masking. In other words, in performing the foreign object detection with the use of the program P, over-detection is prevented by the masking by the image processing unit 11, and under-detection is prevented by the object sensor 6 as the boundary determination unit, thereby increasing the accuracy of the foreign object detection.

[0047] When the object sensor 6 is arranged so as to radiate the irradiation wave along the boundary line between the inside and the outside of the target area A as illustrated in FIG. 1, the foreign object F located on the boundary line can be detected suitably by the object sensor 6. Meanwhile, there is also expected a case in which a foreign object F located immediately on the inner side of the loading/unloading port is not irradiated with the irradiation

wave of the object sensor 6, and in addition, most of the foreign object F is masked through the masking in the image taken by the image pickup devices 5. In such a case, under-detection may occur. To address this problem, instead of or
5 in addition to the object sensor 6 at the position illustrated in FIG. 1, an object sensor 6 may be installed so that the foreign object F can be detected also in a boundary area located more inward. In this manner, when the object sensor 6 is installed for the boundary area located inside
10 the boundary line defined by the loading/unloading port 4, it is optimal to arrange the object sensor 6 as follows.

- For a foreign object F located inward of an area that can be subjected to the object detection by the object sensor 6, the object sensor 6 is arranged so that the foreign object
15 F can be detected also based on the masked image by the program P.

That is,

- The object sensor 6 is arranged so that the boundary area is subjected to the foreign object detection by the
20 object sensor 6.

[0048] The "area that can be subjected to the foreign object detection by the object sensor 6" and the "area in which the foreign object F can be detected also based on the masked image by the program P" may have overlapping portions.

25 [0049] An example of a procedure of the foreign object detection process by the image pickup devices 5, the image processing unit 11, and the object sensor 6 as described

above is explained with reference to a flow chart of FIG. 6. The foreign object detection process described below includes an image taking step (Step S1), a masking step (Step S2), a first object detection step (Step S3), and a second object
5 detection step (Step S4).

[0050] First, images in the target area A are taken by the image pickup devices 5 (Step S1). Subsequently, an area occupied by the transmissive portion (loading/unloading port 4) in the taken images is masked (Step S2). The masking may
10 be performed by the image pickup device 5, or by the image processing unit 11. Further, the object detection processing is executed on the masked images by the program P stored in the image processing unit 11 (Step S3).

[0051] Meanwhile, the object sensor 6 is actuated to
15 detect presence or absence of an object in an area irradiated with the irradiation wave (Step S4). In Step S5, it is determined whether an object of a particular type is detected in the images by the program P, and any object is detected in the irradiated area by the object sensor 6. When an object
20 is detected by one or both thereof, it is determined that there is a foreign object F in the target area A (Step S6). When it is determined that there is a foreign object F, the controller 10 performs various operations that should be performed when the foreign object F is detected. For
25 example, the message that the foreign object has been detected is displayed on the display unit 8. At this time, a text or voice message is delivered, or a background color of

the display unit 8 is changed to alert an operator (driver of the vehicle 1, or the attendant or other personnel at the facility). Further, operations of devices (for example, opening and closing of the loading/unloading port 4, and transport of the pallet 2) may be prohibited as required.

[0052] When no object is detected by any of the program P and the object sensor 6, it is determined that there is no foreign object, and the foreign object detection process ends (Step S7).

[0053] The procedure described above is merely an example, and changes may be made thereto by interchanging the order of the steps as appropriate, or by adding another step. For example, Steps S1 to S3 performing the object detection by the image processing unit 11 and the program P and Step S4 performing the object detection by the object sensor 6 may be interchanged in order, or may be executed in parallel.

Further, the step of determining the result of the object detection has been collectively described here as Step S5, but determination of the result of the object detection by

the image processing unit 11 and the program P, and determination of the result of the object detection by the object sensor 6 may be performed separately from each other.

[0054] As described above, the above-mentioned foreign object detection system according to the first embodiment

includes: the image pickup device 5 configured to take images in the target area A; the image processing unit 11 configured to store the program P for detecting, with the use of deep

learning, an object in the image taken by the image pickup device 5; and the boundary determination unit (object sensor 6) configured to determine a positional relationship between the transmissive portion (loading/unloading port 4) through which the outside of the target area A is visible from the inside of the target area A and an object around the transmissive portion. The foreign object detection system is configured to: mask the area occupied by the transmissive portion (loading/unloading port 4) in the image taken by the image pickup device 5, and detect the object based on the masked image by the program using the deep learning. In this manner, in performing the foreign object detection with the use of the program P, the object detection by the boundary determination unit (object sensor 6) can be executed in combination therewith to increase accuracy of the foreign object detection.

[0055] In the above-mentioned foreign object detection system, the masking may be performed in the image pickup device.

20 [0056] In the above-mentioned foreign object detection system, the masking may also be performed in the image processing unit.

[0057] In the above-mentioned foreign object detection system, the boundary determination unit (object sensor 6) may be an object sensor configured to detect presence or absence of an object in the boundary area between the target area A and the external space. In this manner, the foreign object

detection system can be implemented with a simple device configuration.

[0058] In the above-mentioned foreign object detection system, the object sensor 6 may be configured to detect the irradiation wave radiated along the plane formed by the transmissive portion (loading/unloading port 4). In this manner, the foreign object F located on the boundary line can be suitably detected by the object sensor 6.

[0059] In the foreign object detection system and method described above, the target area A may be the loading/unloading space of the mechanical parking lot, and in this case, the foreign object detection can be executed suitably in the loading/unloading space of the mechanical parking lot.

[0060] Further, the above-mentioned foreign object detection method includes: the image taking step (Step S1) of taking an image in the target area A; the masking step (Step S2) of masking the area occupied by the transmissive portion (loading/unloading port 4) through which the outside of the target area A is visible from the inside of the target area A, in the image taken in the image taking step; the first object detection step (Step S4) of detecting an object based on the image on which the masking step has been performed, by the program using the deep learning; and the second object detection step (Step S4) of detecting presence or absence of an object in the boundary area of the target area A. In this manner, in performing the foreign object detection with the

use of the program P, over-detection is prevented by the masking, and under-detection is prevented by a boundary object sensor (object sensor 6), thereby increasing the accuracy of the foreign object detection.

5 [0061] Accordingly, according to the first embodiment, a foreign object is detectable with high accuracy with a configuration that is as simple as possible.

[0062] FIG. 7 and FIG. 8 show a configuration of a foreign object detection system according to a second
10 embodiment of the present disclosure. A basic configuration of the foreign object detection system according to the second embodiment is the same as that of the first embodiment (see FIG. 1 and FIG. 2) described above, but includes, instead of the object sensor 6, a boundary determination unit
15 12 in the image processing unit 11. The boundary determination unit 12 is configured to determine, based on the images taken by the image pickup devices 5, a positional relationship between the transmissive portion (loading/unloading port 4) and an object (foreign object F or
20 object O) around the transmissive portion. More specifically, the boundary determination unit 12 is configured to determine, based on the positional relationship of the object (foreign object F or object O) captured in the images with respect to the transmissive portion
25 (loading/unloading port 4), whether the object is located inside or outside the target area A.

[0063] In the foreign object detection system

illustrated in FIG. 7, when images are taken by the image pickup devices 5, for example, an image as shown in FIG. 9 is taken by the image pickup device 5a. When the object detection processing is executed on such an image by the

5 program P of the image processing unit 11, two foreign objects F in the target area A, and an object O located outside the loading/unloading port 4 are detected.

[0064] The program P determines the type of each object as well as a position occupied thereby in the image. For

10 example, the type and the position of each object can be displayed and superimposed on the image as illustrated in FIG. 10. Here, around the foreign objects F and the object O that have been detected, ranges occupied thereby are shown by rectangular frames, and an identified type (here, person) of

15 the objects, and a probability that each object is an object of the type are displayed together.

[0065] The boundary determination unit 12 is configured to determine whether each of the foreign objects F and the object O is located inside or outside the target area A,

20 based on at which position each of those objects is located with respect to the loading/unloading port 4 that is a boundary between the target area A and the external space.

[0066] The determination of inside or outside can be performed by, for example, each frame indicating the range

25 occupied by each object, and a vertical relationship with respect to the area occupied by the loading/unloading port 4. In FIG. 10, the area occupied by the loading/unloading port 4

is a substantially quadrangular portion indicated by the broken line in FIG. 10. Based on how much a segment corresponding to a lower side of the frame indicating the position of each object overlaps the substantially

5 quadrangular pixel area, it can be determined whether each object is located inside or outside the loading/unloading port 4.

[0067] In determining the inside or the outside, for example, when a portion of the segment corresponding to the lower side of the frame displayed around each of the foreign objects F or the object O is inside the pixel area occupied by the loading/unloading port 4 and the portion is equal to a certain threshold value (for example, 80%) or more, it is determined that the object is outside the target area A.

10 When the ratio of the portion located inside the pixel area of the frame is less than the threshold value, it is determined that the object is inside the target area A. In the example illustrated in FIG. 10, it can be determined that the two foreign objects F located on the front side are

20 located inside the target area A, and that the object O on the back side is located outside the target area A. The determination method described here is merely an example, and as the method of determining whether each object is located inside or outside based on the images, another appropriate

25 method may be adopted.

[0068] An example of a procedure of the foreign object detection process by the program P of the image processing

unit 11 and the boundary determination unit 12 as described above is explained with reference to a flow chart of FIG. 11. The foreign object detection process described below includes an image taking step (Step S11), an object detection step
5 (Step S12), and a position determination step (Step S15).

[0069] First, images in the target area A are taken by the image pickup devices 5 (Step S11). Subsequently, the object detection processing is executed on the taken images by the program P (Step S12).

10 [0070] In Step S13, it is determined, as a result of the object detection processing, whether some object (foreign object F or object O) that can be regarded as a foreign object F is detected in the image by the program P. When there is no object of the particular type, it is determined
15 that there is no foreign object, and the foreign object detection process ends (Step S14).

[0071] When some object is detected in the image, the foreign object detection process proceeds to Step S15. In Step S15, a position of each detected object with respect to
20 the target area A is determined by the boundary determination unit 12. In Step S16, it is determined whether there is an object determined to be located inside the target area A among the objects detected in Step S12. When all of the above-mentioned objects are determined to be located outside
25 the target area A, it is determined that there is no foreign object, and the foreign object detection process ends (Step S14). When at least some of the objects are determined to be

located inside the target area A, it is determined that there is a foreign object F, and the foreign object detection process ends (Step S17). The procedure described above is merely an example, and changes may be made thereto by

5 interchanging the order of the steps as appropriate, or by adding another step, as described above in the first embodiment.

[0072] As described above, in the second embodiment, in executing the foreign object detection with the use of the
10 program P, the determination of the position by the boundary determination unit 12 is executed in combination therewith to increase the accuracy of the foreign object detection.

[0073] As the boundary determination unit, the object sensor 6 is explained in the first embodiment described
15 above, and the boundary determination unit 12 stored in the image processing unit 11 is explained in the second embodiment. However, the foreign object detection system may be implemented by combining the object sensor 6 and the boundary determination unit 12. Further, for the purpose of
20 increasing the accuracy of the foreign object detection, for example, other sensors may be used in combination.

[0074] Further, in the first and second embodiments described above, the loading/unloading space of the mechanical parking lot has been assumed as the target area A,
25 but a similar foreign object detection system is applicable to any kind of space in which a foreign object should be detected. For example, a power feeding facility for an

electric vehicle may be assumed, or a similar foreign object detection system is also applicable, for example, to security in a warehouse with windows.

[0075] As described above, in the foreign object

5 detection system according to the second embodiment described above, the boundary determination unit 12 is configured to determine whether the object detected in the images taken by the image pickup devices 5 is inside or outside the target area A, based on a positional relationship between the
10 position of the object in the images taken by the image pickup device 5 and the area occupied by the transmissive portion (loading/unloading port 4) in the images. In this manner, in performing the foreign object detection with the use of the program P, the determination of the position by
15 the boundary determination unit 12 can be executed in combination therewith to increase accuracy of the foreign object detection.

[0076] Further, the foreign object detection method according to the second embodiment described above includes:

20 the image taking step (Step S11) of taking an image in the target area A; the object detection step (Step S12) of detecting an object based on the image taken in the image taking step by the program P using the deep learning; and the position determination step (Step S15) of determining whether
25 the object detected in the image is inside or outside the target area, based on the positional relationship between the position of the object in the image and the area occupied by

the transmissive portion (loading/unloading port 4) through which the outside of the target area A is visible from the inside of the target area A in the images. In this manner, in performing the foreign object detection with the use of the program P, the determination of the position of the detected object can be executed in combination therewith to increase the accuracy of the foreign object detection.

[0077] The other components, and actions and effects are to the same as those of the first embodiment described above, and hence description thereof is omitted. However, also in the second embodiment, a foreign object is detectable with high accuracy with a configuration that is as simple as possible.

[0078] The foreign object detection system and method according to the present invention that have been described in the present disclosure are not limited only to the embodiments described above, and it is to be understood that various changes can be made thereto without departing from the scope of the present disclosure.

Reference Signs List

[0079] 1: vehicle, 2: pallet, 4: transmissive portion (loading/unloading port), 5: image pickup device, 5a: image pickup device, 5b: image pickup device, 6: boundary determination unit (object sensor), 7: operation unit, 8: display unit, 9: alarm unit, 10: controller, 11: image processing unit, 12: boundary determination unit, A: target

area, F: object (foreign object), O: object, P: program

Claims

[Claim 1] A foreign object detection system, comprising:

an image pickup device configured to take an image in a target area;

5 an image processing unit configured to store a program for detecting, with use of deep learning, an object in the image taken by the image pickup device; and

a boundary determination unit configured to determine a positional relationship between a transmissive portion
10 through which an outside of the target area is visible from an inside of the target area, and an object around the transmissive portion,

wherein the foreign object detection system is configured to:

15 mask an area occupied by the transmissive portion in the image taken by the image pickup device; and

detect the object based on the masked images by the program using the deep learning.

20 [Claim 2] The foreign object detection system according to claim 1, wherein the masking is performed in the image pickup device.

[Claim 3] The foreign object detection system according to
25 claim 1, wherein the masking is performed in the image processing unit.

[Claim 4] The foreign object detection system according to any one of claims 1 to 3, wherein the boundary determination unit is an object sensor configured to detect presence or absence of an object in a boundary area between the target
5 area and an external space.

[Claim 5] The foreign object detection system according to claim 4, wherein the object sensor is configured to detect an irradiation wave radiated along a plane formed by the
10 transmissive portion.

[Claim 6] The foreign object detection system according to any one of claims 1 to 3, wherein the boundary determination unit is configured to determine whether the object detected
15 in the image taken by the image pickup device is inside or outside the target area, based on a positional relationship between a position of the object in the image taken by the image pickup device, and the area occupied by the transmissive portion in the image.

20

[Claim 7] The foreign object detection system according to any one of claims 1 to 6, wherein the target area is a loading/unloading space of a mechanical parking lot.

25 [Claim 8] A foreign object detection method, comprising:
an image taking step of taking an image in a target area;

a masking step of masking an area occupied by a transmissive portion through which an outside of the target area is visible from an inside of the target area in the image taken in the image taking step;

5 a first object detection step of detecting an object based on the image on which the masking step has been performed, by a program using deep learning; and

a second object detection step of detecting presence or absence of an object in a boundary area of the target area.

10

[Claim 9] A foreign object detection method, comprising:

an image taking step of taking an image in a target area;

15 an object detection step of detecting an object based on the image taken in the image taking step by a program using deep learning; and

20 a position determination step of determining whether the object detected in the image is inside or outside the target area, based on a positional relationship between a position of the object in the image, and an area occupied by a transmissive portion through which an outside of the target area is visible from an inside of the target area in the image.

25 [Claim 10] The foreign object detection method according to claim 8 or 9, wherein the target area is a loading/unloading space of a mechanical parking lot.