OBSTACLE DETECTION SYSTEM AND OBSTACLE DETECTION METHOD

DESCRIPTION

TECHNICAL FIELD

[0001]

The present invention relates to an obstacle detection system that is installed in a moving body such as, for example, a vehicle configured to travel on a traveling path and that detects presence or absence of an obstacle around the moving body and to an obstacle detection method, and specifically relates to an obstacle detection system and an obstacle detection method in which accuracy of obstacle detection is improved.

BACKGROUND ART

[0002]

Various obstacle detection systems for detecting an obstacle in traveling of a crane are proposed (for example, see Patent Document 1). The obstacle detection system according to Patent Document 1 can detect an obstacle by performing scanning of a laser beam along a traveling direction of the crane.

[0003]

To improve safety in traveling of the crane, increasing a detection region in which an obstacle is detected is conceivable. For example, the detection region can be increased in a traversing direction of the crane by using devices referred to as a LiDAR (light detection and ranging) and a 3D laser scanner. Moreover, installing the LiDAR and the like at relatively high positions in the crane can increase the detection region in the traveling direction and

the traversing direction.

[0004]

However, in the case where the LiDAR and the like are installed at high positions in a crane, there is a possibility that a blind spot where the laser beam does not reach is formed at a position near the crane and close to a traveling path. The formation of the blind spot may reduce accuracy of obstacle detection.

PRIOR ART DOCUMENT

PATENT DOCUMENT

[0005]

Patent Document 1: Japanese patent application Kokai publication No. 2018-105822

SUMMARY OF THE INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

[0006]

The present invention has been made in view of the above-mentioned problems, and an object thereof is to provide an obstacle detection system and an obstacle detection method in which accuracy of obstacle detection is improved.

MEANS FOR SOLVING THE PROBLEM

[0007]

An obstacle detection system for achieving the above-mentioned object is an obstacle detection system including: an emission unit installed in a moving body and configured to emit a laser beam while changing emission angles in a horizontal direction and an up-down direction; a reception unit configured to receive a reflection beam of the laser beam; a detection region setting mechanism configured to set, in advance, detection regions in a region of reflection

points where the laser beam is reflected in a case where an obstacle is absent; and a determination mechanism configured to determine presence or absence of an obstacle depending on the reflection beam reflected inside the detection regions, and is characterized in that the detection region setting mechanism has a configuration to set a front detection region formed in front of the moving body in a traveling direction of the moving body, a first peripheral detection region formed to surround a periphery of the front detection region, and a second peripheral detection region formed to surround a periphery of the first peripheral detection region.

[0008]

An obstacle detection method for achieving the above-mentioned object is an obstacle detection method of detecting presence or absence of an obstacle by emitting a laser beam from an emission unit installed in a moving body while changing emission angles in a horizontal direction and an up-down direction and receiving a reflection beam of the laser beam with a reception unit, the obstacle detection method including: a detection region setting step of setting a region of reflection points where the laser beam is reflected in a case where an obstacle is absent as detection regions in advance; and a determination step of determining presence or absence of an obstacle depending on the reflection beam reflected inside the detection regions, the obstacle detection method characterized in that the detection region setting step has a configuration to set, in advance, a front detection region formed in front of the moving body in a traveling direction of the moving body, a first peripheral detection region formed to surround a

periphery of the front detection region, and a second peripheral detection region formed to surround a periphery of the first peripheral detection region.

EFFECTS OF THE INVENTION

[0009]

According to the present invention, presence or absence of entrance of an obstacle into the blind spot formed in the front region can be estimated from states of the first peripheral detection region and the second peripheral detection region formed around the blind spot. This is advantageous in improving accuracy of obstacle detection.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010]

[Fig. 1] Fig. 1 is an explanatory diagram illustrating an outline of an obstacle detection system.

[Fig. 2] Fig. 2 is an explanatory diagram illustrating detection regions in plan view.

[Fig. 3] Fig. 3 is an explanatory diagram illustrating the detection regions in side view.

[Fig. 4] Fig. 4 is an explanatory diagram illustrating the detection regions in a manner separated from one another in an up-down direction.

[Fig. 5] Fig. 5 is an explanatory diagram illustrating a flow of control of the obstacle detection system.

[Fig. 6] Fig. 6 is a table illustrating data included in the obstacle detection system.

[Fig. 7] Fig. 7 is a table illustrating data included in the obstacle detection system.

[Fig. 8] Fig. 8 is an explanatory diagram illustrating relationships between the detection regions and reflection

points Pmn.

[Fig. 9] Fig. 9 is an explanatory diagram illustrating combinations of determination results in the detection regions.

[Fig. 10] Fig. 10 is an explanatory diagram illustrating a state where a worker in Fig. 8 has moved.

[Fig. 11] Fig. 11 is an explanatory diagram illustrating a state where the worker in Fig. 10 has moved.

[Fig. 12] Fig. 12 is an explanatory diagram illustrating patterns of transition of situations Qn.

[Fig. 13] Fig. 13 is an explanatory diagram illustrating a modification of Fig. 4.

[Fig. 14] Fig. 14 is an explanatory diagram illustrating combinations of determination results in the detection regions.

[Fig. 15] Fig. 15 is an explanatory diagram illustrating a modification of Fig. 10.

MODES FOR CARRYING OUT THE INVENTION

[0011]

An obstacle detection system and an obstacle detection method are explained below based on an embodiment illustrated in the drawings. In the drawings, a traveling direction of a moving body such as a crane is indicated by the arrow y, a traversing direction traversing the traveling direction y at a right angle is indicated by the arrow x, and an up-down direction is indicated by the arrow z.

[0012]

As illustrated in Fig. 1, an obstacle detection system 1 is installed in a moving body 2 such as, for example, a gantry crane. The gantry crane includes traveling devices

3 configured to travel in the traveling direction y, four leg members 4 arranged above the traveling devices 3 and extending in the up-down direction z, two beam members 5 extending in the traversing direction x and connecting upper ends of the leg members 4 facing one another in the traversing direction x, a trolley 6 configured to be movable in the traversing direction x along the beam members 5, and a rigging tool 7 suspended from the trolly 6 by a wire rope. The gantry crane forming the moving body 2 performs cargo handling of containers with the rigging tool 7 while traveling on a traveling surface 8 in the traveling direction y.

[0013]

The obstacle detection system 1 includes emission units 9a configured to emit laser beams toward the traveling surface 8 and reception units 9b configured to receive reflection beams reflected on the traveling surface 8. The reception units 9b are arranged near the emission units 9a. In this embodiment, the emission units 9a and the reception units 9b (hereinafter, collectively referred to as sensors 9 in some cases) are installed in four traveling devices 3. The positions where the sensors 9 are installed are not limited to those described above, and may be installed at other positions such as side surfaces of the leg members 4 as appropriate.

[0014]

Each of the sensors 9 is formed of, for example, a LiDAR or a 3D laser scanner. The emission unit 9a of the sensor 9 has a configuration to emit laser beams. The emission unit 9a emits the laser beams while changing

emission angles in the horizontal directions x and y and the up-down direction z. In Fig. 1, ranges R0 to which the laser beams are emitted on the traveling surface 8 are indicated by the broken lines for the sake of explanation.

[0015]

The obstacle detection system 1 may be configured to emit the laser beams only from the sensors 9 on the front side in the traveling direction y of the moving body 2, or may be configured to emit the laser beams from the sensors 9 on the front side and the rear side.

[0016]

Each of the sensors 9 obtains, as data, the emission angles of the laser beam emitted toward the traveling surface 8 and time taken from the emission of the laser beam to obtaining the reflection beam. The sensor 9 may have a configuration to obtain, as data, a distance from the sensor 9 to a reflection point where the laser beam is reflected, instead of the time taken to the obtaining of the reflection beam.

The sensor 9 is not limited to the LiDAR or the like, and may be formed of another device as long as it has a configuration that can emit the laser beam and obtain the distance to the traveling surface 8.

[0017]

The obstacle detection system 1 includes a detection region setting mechanism 10 configured to set, in advance, detection regions in a region of the reflection points where the laser beams are reflected in the case where an obstacle is absent and a determination mechanism 11 configured to determine presence or absence of an obstacle depending on

the reflection beams reflected inside the detection regions. The detection region setting mechanism 10 and the determination mechanism 11 can be configured by using various publicly-known computers. The detection region setting mechanism 10 and the like include a central processing unit (CPU), a main storage unit (memory), and an auxiliary storage unit (for example, HDD). The detection region setting mechanism 10 and the like may also include an input unit (keyboard, mouse) and an output unit (display, printer).

[0018]

The detection region setting mechanism 10 and the like are installed in, for example, a driver room, a machine room, an electric room, or the like of the gantry crane. A location where the detection region setting mechanism 10 and the like are installed is not limited to those described above. In the case where the gantry crane is remotely operated, the detection region setting mechanism 10 and the like may be arranged near an operation panel to perform the remote operations. The detection region setting mechanism 10 and the like are connected to the sensors 9 via wires or wirelessly.

[0019]

As illustrated in Figs. 2 and 3, the detection region setting mechanism 10 can set multiple detection regions in advance. The detection region setting mechanism 10 sets a front detection region Ra formed in front of the moving body 2 in the traveling direction y of the moving body 2, a first peripheral detection region Rb formed to surround the front detection region Ra, and a second peripheral detection region Rc formed to surround the first peripheral detection region

Rb. In Figs. 2 and 3, the front detection region Ra, the first peripheral detection region Rb, and the second peripheral detection region Rc are indicated by dot-dash lines, and an emission direction of each laser beam is indicated by the broken line for the sake of explanation. Moreover, an emission angle θ [deg] of the laser beam in the horizontal directions x and y is illustrated such that the left side (upper side in Fig. 2) of the traveling direction of the moving body 2 is positive and the right side (lower side in Fig. 2) is negative with the front side of the moving body 2 being 0°. As illustrated in Fig. 3, an emission angle φ [deg] of the laser beam in the up-down direction z is illustrated such that the lower side is negative with the horizontal direction being 0°.

[0020]

The front detection region Ra is formed along the traveling surface 8 with which wheels of the gantry crane come into contact. The front detection region Ra is set to include a region where the traveling device 3 passes in the traversing direction x. In the case where an obstacle is absent in the front detection region Ra, the traveling device 3 can continue to travel without coming into contact with an obstacle. The front detection region Ra is set as, for example, a space with a rectangular parallelepiped shape. As illustrated in Fig. 3, since the front detection region Ra has a small dimension in the up-down direction z, the reflection beam can be obtained from the inside of the detection region also in the case where the traveling surface 8 is uneven. It is possible to avoid a trouble of erroneous detection of unevenness of the traveling surface 8 as an

obstacle. Moreover, in the front detection region Ra, no laser beam is emitted to a portion close to the traveling device 3, and a blind spot region R1 being a blind spot of the sensor 9 is formed. In Fig. 3, the blind spot region R1 is shaded with diagonal lines for the sake of explanation.

[0021]

The first peripheral detection region Rb is set to surround the front detection region Ra. In the present description, to surround the front detection region Ra refers to a state where an obstacle that reaches the front detection region Ra always passes the first peripheral detection region Rb. For example, a state where a portion excluding a portion adjacent to the moving body 2 in the front detection region Ra is covered with the first peripheral detection region Rb as in the embodiment illustrated in Fig. 2 can be considered as to surround the front detection region Ra. In this embodiment, a rear side (left side in Fig. 2) of a rectangle forming the front detection region Ra overlaps a rear side (left side in Fig. 2) of a rectangle forming the first peripheral detection region Rb in plan view illustrated in Fig. 2. Since the traveling device 3 is present behind the rectangle of the front detection region Ra, an obstacle cannot enter the front detection region Ra from the rear side of the moving body 2. It can be also said that no first peripheral detection region Rb needs to be formed in a portion of the front detection region Ra where an obstacle cannot enter.

Moreover, a state where a periphery of the front detection region Ra also including the rear side (left side in Fig. 2) of the front detection region Ra is completely

covered with the first peripheral detection region Rb in plan view can be considered as to surround the front detection region Ra.

[0022]

A range that is outside the front detection region Ra and that is inside the first peripheral detection region Rb is a range that does not directly affect traveling of the moving body 2. Even if an obstacle is present in this range, the moving body 2 can continue to travel without coming into contact with the obstacle.

[0023]

Similarly, the second peripheral detection region Rc is set to surround the first peripheral detection region Rb. An obstacle that reaches the first peripheral detection region Rb always passes the second peripheral detection region Rc.

[0024]

Fig. 4 is a diagram illustrating ranges of the front detection region Ra and the like in a manner separated from one another in the up-down direction z for the sake of explanation. As illustrated in Fig. 4, the first peripheral detection region Rb may be set to a range overlapping the entire front detection region Ra. Accordingly, the range included in the front detection region Ra is also included in the first peripheral detection region Rb. Similarly, the second peripheral detection region Rc may be set to a range overlapping the entire first peripheral detection region Rb. The entire front detection region Ra and the entire first peripheral detection region Rb are included inside the second peripheral detection region Rc.

[0025]

In the case where an obstacle is absent, the reflection beams reflected on the traveling surface 8 return to the sensor 9. In the case where an obstacle is present, the state is such that the reflection beams reflected outside the detection region return to the sensor 9, or no reflection beams return to the sensor 9. For example, the determination mechanism 11 has a configuration to calculate a fulfillment ratio that is a proportion of the number of reflection beams reflected inside the front detection region Ra to the total number of laser beams emitted toward the front detection region Ra, and to determine that an obstacle is absent in the case where this fulfillment ratio is equal to or higher than a predetermined threshold and determine that an obstacle is present in the case where the fulfillment ratio is smaller than the threshold. Specifically, the determination mechanism 11 determines that an obstacle is absent in the case where the front detection region Ra is sufficiently visible from the sensor 9.

[0026]

The determination mechanism 11 determines presence or absence of an obstacle by calculating the fulfillment ratio in each of the first peripheral detection region Rb and the second peripheral detection region Rc, in addition to the front detection region Ra. The determination mechanism 11 determines presence or absence of an obstacle for each of the detection regions such as the front detection region Ra.

[0027]

The method in which the determination mechanism 11 determines presence or absence of an obstacle is not limited

to that described above. For example, the determination mechanism 11 may determine presence or absence of an obstacle by comparing the number of reflection beams reflected inside the front detection region Ra and the number of reflection beams reflected outside the front detection region Ra, among the laser beams emitted toward the front detection region Ra.

[0028]

The obstacle detection system 1 may include a command mechanism 12 configured to transmit a command to the moving body 2 depending on a determination result of the determination mechanism 11. The command mechanism 12 may be formed of various publicly-known computers like the detection region setting mechanism 10 and the determination mechanism 11. For example, the detection region setting mechanism 10, the determination mechanism 11, and the command mechanism 12 may be incorporated in one computer. The command mechanism 12 is not an essential constituent element of the obstacle detection system 1.

[0029]

The command mechanism 12 may be configured to transmit the command to the moving body 2, for example, in the case where the determination mechanism 11 determines that an obstacle is present in the blind spot region R1 or the front detection region Ra. In this case, a deceleration command, a stop command, an emergency stop command, and the like are conceivable as the command. The deceleration command is a command of decelerating the moving body 2 in a predetermined range. The deceleration command causes the traveling speed of the moving body 2 to decrease from the current speed to,

for example, 50% of the current speed, or decrease to a speed set in advance such as, for example, 8 km per hour. The stop command is a command of decelerating the moving body 2 in a predetermined range and then stopping the moving body 2. The emergency stop command is a command of decelerating the moving body 2 at a maximum rate in an allowable range and then stopping the moving body 2.

[0030]

The command mechanism 12 may be configured not to transmit the command to the moving body 2, for example, in the case where the determination mechanism 11 determines that an obstacle is present in the first peripheral detection region Rb or the second peripheral detection region Rc. In this case, traveling of the moving body 2 is not affected even if an obstacle is present in the first peripheral detection region Rb and the second peripheral detection region Rc.

[0031]

The command mechanism 12 may have a configuration to notify the driver of the moving body 2 that an obstacle is present. The driver can operate the moving body 2 with reference to the command from the command mechanism 12. In this case, the command mechanism 12 is configured to send the notification to the driver instead of sending a control signal such as the deceleration command to the moving body 2.

[0032]

As illustrated in Fig. 5, the obstacle detection system 1 first sets the detection regions (hereinafter, referred to as detection region setting step S1 in some cases). In the

detection region setting step S1, the front detection region Ra, the first peripheral detection region Rb, and the second peripheral detection region Rc are set. The detection regions set in the detection region setting step S1 are not limited to those described above. A detection region may be added further in front of the front detection region Ra in the traveling direction y of the moving body 2, or a detection region may be set outside the second peripheral detection region Rc. Moreover, the first peripheral detection region Rb and the like may be divided into multiple regions. The detection regions only need to be set once.

[0033]

Figs. 6 and 7 illustrate examples of data obtained from the sensor 9 and stored in the obstacle detection system 1. The resolutions of the emission angle θ of the laser beam in the horizontal directions x and y and the emission angle φ of the laser beam in the up-down direction z are determined in advance as the performances of the sensor 9. Here, explanation is given by using, as an example, the case where the resolution of the angle φ in the up-down direction z in a range of -10° to -20° is 5° and the resolution of the angle θ in the horizontal directions x and y in a range of -135° to +135° is 5°. For example, a sensor whose resolution is in a range of 0.125° to 1.000° and in which the number of times of scanning is 5 to 100 Hz can be used as an actual sensor.

[0034]

As illustrated in Figs. 6 and 7, a reflection point Pmn corresponding to the angle φ in the up-down direction z and the angle θ in the horizontal directions x and y is

determined in advance. Fig. 8 illustrates a distribution state of the reflection points Pmn on the traveling surface 8. In this embodiment, first, the sensor 9 performs scanning of the laser beam with the angle θ in the horizontal directions x and y varied from -135° to 135° and with the angle φ in the up-down direction z fixed to -10°. The reflection points Pmn corresponding to this laser beam are P1-1 to P1-55. Next, the sensor 9 performs scanning of the laser beam with the angle θ in the horizontal directions x and y varied and with the angle φ in the up-down direction z fixed to -15°. The reflection points Pmn corresponding to this laser beam are P2-1 to P2-55.

[0035]

In the detection region setting step S1, the detection region corresponding to each reflection point Pmn is set. Explanation is given by using Fig. 8 as an example. For example, since the reflection point P1-1 is included in none of the detection regions, the detection region thereof is set to "none". Since the reflection points P1-19 and P1-28 are included in the second peripheral detection region Rc, the detection regions thereof are set to "Rc" (see Fig. 6). Since the reflection points P2-19 and P3-19 illustrated in Fig. 8 are included in the first peripheral detection region Rb, the detection regions thereof are set to "Rb". Since the reflection point P2-29 is included in the front detection region Ra, the detection region thereof is set to "Ra" (see Fig. 7). As described above, in the detection region setting step S1, the detection region corresponding to each reflection point Pmn is set as illustrated in Figs. 6 and 7. Changing the detection region to be set for each reflection

point Pmn can change the range of each of the detection regions in the horizontal directions x and y.

[0036]

As illustrated in Figs. 6 and 7, time (measurement time tmn) from the emission of the laser beam to the obtaining of the reflection beam in the case where an obstacle is absent is determined in advance for each reflection point Pmn. The measurement time tmn is inherently determined if the angle φ in the up-down direction z and the height at which the sensor 9 is installed in the moving body 2 are determined.

[0037]

In the detection region setting step S1, allowable time tn having a predetermined range is set while being centered on the measurement time tmn. The range of this allowable time tn is determined based on the dimension of the detection region in the up-down direction z. Changing the range of the allowable time tn can change the range of the detection region in the up-down direction z.

[0038]

For example, in the case where the gantry crane forming the moving body 2 travels or performs cargo handling, the time from the emission of the laser beam from the sensor 9 to the obtaining of the reflection beam is measured (hereinafter, referred to as measurement step S2 in some cases). In the measurement step S2, the measurement time tmn is obtained for each reflection point Pmn.

[0039]

First, comparison of whether the measurement time tmn is within the range of the allowable time tn is performed for each reflection point Pmn. A result of the comparison

is stored in the obstacle detection system 1. Next, for example, presence or absence of an obstacle is determined for each of the detection regions such as the front detection region Ra (hereinafter, referred to as determination step S3 in some cases).

[0040]

In the determination step S3, for example, in the case where the measurement time tmn is within the range of the allowable time tn in, for example, 90% or more of 1,000 reflection points Pmn in the front detection region Ra, the determination mechanism 11 determines that an obstacle is absent in the front detection region Ra. The threshold for the determination of absence of an obstacle is not limited to 90% described above. The threshold can be determined as appropriate depending on the size of the obstacle to be detected. Moreover, the configuration may be such that the threshold is changed depending on weather or the like.

[0041]

The command mechanism 12 transmits the command to the moving body 2 depending on the result obtained in the determination step S3 (hereinafter, referred to as command step S4 in some cases). For example, in the case where an obstacle is present in the front detection region Ra, the command mechanism 12 transmits the stop command to the moving body 2. For example, the command mechanism 12 may be configured not to transmit the command to the moving body 2 in the case where an obstacle is present in the first peripheral detection region Rb or the second peripheral detection region Rc.

[0042]

In the above-mentioned example, in the case where an obstacle is present in the front detection region Ra, the moving body 2 is stopped by the stop command. In the case where an obstacle is present in the first peripheral detection region Rb or the second peripheral detection region Rc, the moving body 2 continues to travel.

[0043]

The obstacle detection system 1 repeats the measurement step S2, the determination step S3, and the command step S4, and repeatedly checks whether the moving body 2 is in a state where it can safely travel.

[0044]

After the moving body 2 is stopped due to an obstacle, a worker or the like performs safety check. After the safety is confirmed, the traveling of the moving body 2 is resumed. The detection by the obstacle detection system 1 is resumed with the resuming of the traveling of the moving body 2. The configuration may be such that no detection region setting step S1 is performed in this case, the detection regions are reset in the detection region setting step S1, or already-set values are read. In the case where no detection region setting step S1 is performed, the control starts from the measurement step S2.

[0045]

The command step S4 is not an essential constituent element of the obstacle detection method. For example, in the case where the driver of the moving body 2 decelerates or stops the moving body 2 by viewing the result of the determination step S3, the command step S4 is unnecessary.

[0046]

Since the first peripheral detection region Rb and the second peripheral detection region Rc are formed to be distinguished from the front detection region Ra, the control of the moving body 2 in the case where an obstacle is detected can be set to different states for the front detection region Ra, the first peripheral detection region Rb, and the like. For example, it is possible to stop the moving body 2 in the case where an obstacle is detected in the front detection region Ra, and continue the traveling of the moving body 2 in the case where an obstacle is detected in the first peripheral detection region Rb and the like. The first peripheral detection region Rb and the like can be set in a range in which a chassis travels and a range in which a container is loaded near the gantry crane that is the moving body 2.

[0047]

Since the first peripheral detection region Rb and the like are set around the front detection region Ra, presence or absence of entrance of an obstacle into the blind spot region R1 formed in part of the front detection region Ra can be estimated from the states of the first peripheral detection region Rb and the like. A worker or the like who is an obstacle for the moving body 2 must pass the first peripheral detection region Rb and the second peripheral detection region Rc to move to the blind spot region R1. Accordingly, the obstacle detection system 1 can detect presence or absence of an obstacle moving to the blind spot region R1. Specifically, in the case where a worker or the like enters the blind spot region R1 from the second peripheral detection region Rc via the first peripheral

detection region Rb, the state is such that an obstacle is detected in none of the regions after the worker or the like passes the first peripheral detection region Rb. Accordingly, the obstacle detection system 1 can detect presence of an obstacle.

[0048]

Operations of the obstacle detection system 1 are explained by using, as an example, the case where a worker 13 moves toward the blind spot region R1 from a direction of the angle θ in the horizontal directions x and y=-45° as illustrated in Fig. 8. In Fig. 8, the worker 13 is indicated by circles whose inside is shaded with diagonal lines for the sake of explanation.

Fig. 9 illustrates situations Qn that are each a combination of the determination results in the respective detection regions Ra, Rb, and Rc and commands corresponding to the respective situations Qn.

[0049]

In the case where the worker 13 is at the position indicated by the broken line in Fig. 8, an obstacle is determined to be absent in all of the detection regions Ra, Rb, and Rc. This situation is referred to as third preliminary situation Q3.

[0050]

In the case where the worker 13 is at the position indicated by the solid line in Fig. 8, no reflection beams from the inside of the second peripheral detection region Rc are obtained around the reflection point P1-19. As a result, an obstacle is determined to be present in the second peripheral detection region Rc. This situation is referred

to as second preliminary situation Q2.

[0051]

In the case where the worker 13 is at the position indicated by the broken line in Fig. 10, no reflection beams from the inside of the first peripheral detection region Rb are obtained around the reflection points P2-19 and P3-19. As a result, an obstacle is determined to be present in the first peripheral detection region Rb. This situation is referred to as first preliminary situation Q1. In this case, since the worker 13 is also inside the second peripheral detection region Rc, an obstacle is determined to be present also in the second peripheral detection region Rc.

[0052]

In the case where the worker 13 is at the position indicated by the solid line in Fig. 10, the worker 13 is in the blind spot region R1 that is the blind spot of the sensor 9. In this case, an obstacle is determined to be absent in all of the detection regions Ra, Rb, and Rc. This situation is referred to as emergency situation Q5. This is a situation in which the sensor 9 cannot see the worker 13 approaching from the direction of the angle θ in the horizontal directions x and y=-45°. This emergency situation Q5 is the same as the third preliminary situation Q3 in that an obstacle is determined to be absent in all of the detection regions Ra, Rb, and Rc. In the case where an obstacle is determined to be absent in all of the detection regions Ra, Rb, and Rc from the first preliminary situation Q1, the situation is determined to be the emergency situation Q5 instead of the third preliminary situation Q3. The emergency situation Q5 is a situation where an obstacle is

present in the blind spot region R1. In this case, for example, the command mechanism 12 transmits the emergency stop command to the moving body 2.

[0053]

In the case where the worker 13 is at the position indicated by the solid line in Fig. 11, no reflection beams from the inside of the front detection region Ra are obtained around the reflection point P3-27. As a result, an obstacle is determined to be present in the front detection region Ra. This situation is referred to as emergency situation Q4. In this case, since the worker 13 is also inside the first peripheral detection region Rb and the second peripheral detection region Rc, an obstacle is determined to be present also in the first peripheral detection region Rb and the second peripheral detection region Rc. In this case, for example, the command mechanism 12 transmits the emergency stop command to the moving body 2.

[0054]

In the case where the worker 13 moves from the position indicated by the broken line to the outside of the second peripheral detection region Rc via the second peripheral detection region Rc in Fig. 11, the situation changes from the first preliminary situation Q1 to the third preliminary situation Q3 via the second preliminary situation Q2. In the case where an obstacle is determined to be absent in all of the detection regions Ra, Rb, and Rc after a situation changes from the first preliminary situation Q1 via the second preliminary situation Q2 as described above, the situation is determined to be the third preliminary situation Q3 instead of the emergency situation Q5.

[0055]

In the first preliminary situation Q1, the second preliminary situation Q2, and the third preliminary situation Q3, even if an obstacle is present, the obstacle is not close enough to hinder the traveling of the moving body 2. Accordingly, these situations can be considered as situations in which the stopping of the moving body 2 or the like does not have to be immediately performed. The emergency situations Q4 to Q5 can be considered as situations in which the stopping of the moving body 2 or the like has to be immediately performed.

[0056]

As illustrated in Fig. 12, patterns of transition of the situations Qn are limited. The obstacle detection system 1 can prepare for the case of transition to the emergency situations Q4 to Q5 by grasping transition of the preliminary situations Q1 to Q3. This is advantageous in improving accuracy of obstacle detection by the obstacle detection system 1. Since direct transition from the first preliminary situation Q1 to the third preliminary situation Q3 does not occur as illustrated in Fig. 12, the obstacle detection system 1 can distinguish the third preliminary situation Q3 from the emergency situation Q5.

[0057]

In the case where the situation becomes the first preliminary situation Q1, there is a possibility of transition to the emergency situations Q4 to Q5. Accordingly, for example, a speed limiting command for limiting a maximum speed of the moving body 2 may be given in the first preliminary situation Q1.

[0058]

As illustrated in Fig. 13, the first peripheral detection region Rb may be set in a range not overlapping the front detection region Ra. In this case, a range included in the front detection region Ra is not included in the first peripheral detection region Rb. Similarly, the second peripheral detection region Rc may be set in a range not overlapping the first peripheral detection region Rb. In this case, the ranges included in the front detection region Ra and the first peripheral detection region Rb are not included in the second peripheral detection region Rc.

[0059]

Fig. 14 illustrates the situations Qn that are each a combination of the determination results in the respective detection regions Ra, Rb, and Rc and commands corresponding to the respective situations Qn. As illustrated in Fig. 14, in the case where an obstacle is present in the first peripheral detection region Rb, no obstacle is detected in the second peripheral detection region Rc unlike the example illustrated in Fig. 9 (first preliminary situation Q1'). Similarly, in the case where an obstacle is present in the front detection region Ra, no obstacle is detected in the first peripheral detection region Rb or the second peripheral detection region Rc. Other portions are the same as those in the example illustrated in Fig. 9.

[0060]

The measurement by the obstacle detection system 1 may be continued while the gantry crane forming the moving body 2 is halted. Presence or absence of an obstacle in the blind spot region R1 can be detected when the moving body 2 is

restarted. Continuation of the measurement while the gantry crane is halted is not an essential constituent element. Accidents caused by an obstacle in the blind spot region R1 may be prevented by a configuration in which a bumper switch is installed in each traveling device 3. The bumper switch is configured to transmit the emergency stop command to the gantry crane when the bumper switch comes into contact with an obstacle. Since this is performed when the gantry crane starts to travel and the speed is extremely low, the gantry crane can be immediately stopped.

[0061]

As illustrated in Fig. 15, the first peripheral detection region Rb and the second peripheral detection region Rc may each be divided into right and left regions in the traveling direction y. This is advantageous in improving the accuracy of the obstacle detection by the obstacle detection system 1. Specifically, a first peripheral detection region Rb1 on the left side of the traveling direction of the moving body 2 and a first peripheral detection region Rb2 on the right side form the first peripheral detection region Rb along the traveling direction y of the moving body 2. Moreover, a second peripheral detection region Rc1 on the left side and a second peripheral detection region Rc2 on the right side form the second peripheral detection region Rc.

[0062]

Explanation is given by using, as an example, the case where a container 14 is present in the second peripheral detection region Rc and the worker 13 is present in the first peripheral detection region Rb as indicated by the broken

line as illustrated in Fig. 15. In the case where the peripheral detection regions Rb and Rc are not divided, the obstacle detection system 1 determines this situation as the first preliminary situation Q1. When the worker 13 moves to the blind spot region R1 from this situation, there is a possibly that the obstacle detection system 1 recognizes the situation as the second preliminary situation Q2. In other words, there is a possibility that the obstacle detection system 1 cannot detect the worker 13 in the blind spot region R1.

[0063]

On the contrary to the above-mentioned case, in the case where the peripheral detection regions Rb and Rc are divided, a change from the first preliminary situation Q1 to the emergency situation Q5 is detected on the right side of the moving body 2. The worker 13 in the blind spot region R1 can be detected. The second preliminary situation Q2 is maintained on the left side of the moving body 2. The container 14 does not affect the traveling of the moving body 2.

[0064]

According to this configuration, since presence or absence of an obstacle can be detected for each of the divided periphery detection regions Rb and Rc, a situation of movement of an obstacle can be accurately grasped. Particularly, in the case where there are multiple obstacles, the detection can be performed for each of the obstacles. This is advantageous in improving the accuracy of the obstacle detection.

[0065]

The method of dividing the peripheral detection regions Rb and Rc is not limited to the above-mentioned method, and may be any method as long as the configuration is such that at least one of the first peripheral detection region Rb and the second peripheral detection region Rc is divided into multiple regions. Moreover, the number of divided regions is not limited to two. For example, each of the peripheral detection regions Rb and Rc may be divided into four regions of front, rear, left, and right. The number of divided regions may be larger than four. Moreover, the number of divided regions may differ between the first peripheral detection region Rb and the second peripheral detection region Rc. For example, the configuration may be such that the first peripheral detection region Rb is divided into four regions of front, rear, left, and right, and the second peripheral detection region Rc is divided into two regions of left and right.

[0066]

The obstacle detection system 1 may have a configuration to perform determination for each obstacle. An obstacle that simultaneously covers the reflection points Pmn close to each other in plan view can be considered as a single obstacle. A configuration to perform the determination of presence or absence of an obstacle for each reflection point Pmn instead of performing the determination in units of regions can detect each of obstacles. Specifically, in the case where there are multiple obstacles, movements of the respective obstacles can be individually identified. Whether each obstacle has entered the blind spot region R1 or not can be determined.

[0067]

A calculation amount in the determination mechanism 11 increases as compared with the case where presence or absence of an obstacle is detected for each of the peripheral detection regions Rb and Rc. In the case where the number of obstacles expected in advance is small, it is desirable to determine presence or absence of an obstacle for each region. This is because it is possible to suppress the calculation amount in the determination mechanism 11 and obtain the determination result in a relatively short time.

[0068]

In the case where the number of obstacles expected in advance is large, it is desirable to perform the determination for each obstacle. Although the calculation amount in the determination mechanism 11 increases, since obstacles can be accurately detected, this is advantageous in improving safety.

The moving body 2 is not limited to a crane. The obstacle detection system 1 can be also applied to a chassis configured to travel in a container terminal, an automobile configured to travel on a public road, or the like.

EXPLANATION OF REFERENCE NUMERALS

[0069]

1 obstacle detection system

2 moving body

3 traveling device

4 leg member

5 beam member

6 trolly

7 rigging tool

8	traveling surface
9	sensor
9a	emission unit
9b	reception unit
10	detection region setting mechanism
11	determination mechanism
12	command mechanism
13	worker
14	container
x	traversing direction
y	traveling direction
z	up-down direction
R0	range to which laser beams are emitted
R1	blind spot region
Ra	front detection region
Rb	first peripheral detection region
Rc	second peripheral detection region
θ	emission angle in horizontal directions
φ	emission angle in up-down direction
Q1	first preliminary situation
Q2	second preliminary situation
Q3	third preliminary situation
Q4	emergency situation
Q5	emergency situation

CLAIMS

[Claim 1] An obstacle detection system comprising: an emission unit installed in a moving body and configured to emit a laser beam while changing emission angles in a horizontal direction and an up-down direction; a reception unit configured to receive a reflection beam of the laser beam; a detection region setting mechanism configured to set, in advance, detection regions in a region of reflection points where the laser beam is reflected in a case where an obstacle is absent; and a determination mechanism configured to determine presence or absence of an obstacle depending on the reflection beam reflected inside the detection regions, wherein

the detection region setting mechanism has a configuration to set a front detection region formed in front of the moving body in a traveling direction of the moving body, a first peripheral detection region formed to surround a periphery of the front detection region, and a second peripheral detection region formed to surround a periphery of the first peripheral detection region.

[Claim 2] The obstacle detection system according to claim 1, wherein the determination mechanism has a configuration to determine that an obstacle is present in a blind spot region being a blind spot of the front detection region in a case where an obstacle is determined to be present in the first peripheral detection region and then an obstacle is determined to be absent in all of the front detection region, the first peripheral detection region, and the second peripheral detection region without transition to a state

where an obstacle is determined to be absent in the first peripheral detection region and an obstacle is determined to be present in the second peripheral detection region.

[Claim 3] The obstacle detection system according to claim 2, comprising a command mechanism configured to transmit a command to the moving body depending on a determination result of the determination mechanism, wherein

the command mechanism has a configuration to transmit the command to the moving body in a case where the determination mechanism determines that an obstacle is present in the blind spot region or the front detection region.

[Claim 4] The obstacle detection system according to any one of claims 1 to 3, wherein

at least one of the first peripheral detection region or the second peripheral detection region is divided into two or more detection regions, and

the determination mechanism has a configuration to determine presence or absence of an obstacle for each of the plurality of detection regions.

[Claim 5] An obstacle detection method of detecting presence or absence of an obstacle by emitting a laser beam from an emission unit installed in a moving body while changing emission angles in a horizontal direction and an up-down direction and receiving a reflection beam of the laser beam with a reception unit, the obstacle detection method comprising: a detection region setting step of setting

a region of reflection points where the laser beam is reflected in a case where an obstacle is absent as detection regions in advance; and a determination step of determining presence or absence of an obstacle depending on the reflection beam reflected inside the detection regions, wherein

the detection region setting step has a configuration to set, in advance, a front detection region formed in front of the moving body in a traveling direction of the moving body, a first peripheral detection region formed to surround a periphery of the front detection region, and a second peripheral detection region formed to surround a periphery of the first peripheral detection region.

[Claim 6] The obstacle detection method according to claim 5, wherein the determination step has a configuration to determine that an obstacle is present in a blind spot region being a blind spot of the front detection region in a case where an obstacle is determined to be present in the first peripheral detection region and then an obstacle is determined to be absent in all of the front detection region, the first peripheral detection region, and the second peripheral detection region without transition to a state where an obstacle is determined to be absent in the first peripheral detection region and an obstacle is determined to be present in the second peripheral detection region.

[Claim 7] The obstacle detection method according to claim 6, comprising a command step of transmitting a command to the moving body depending on a determination result of the

determination step, wherein

the command step has a configuration to transmit the command to the moving body in a case where an obstacle is determined to be present in the blind spot region or the front detection region.

[Claim 8] The obstacle detection method according to any one of claims 5 to 7, wherein

at least one of the first peripheral detection region or the second peripheral detection region is divided into two or more detection regions, and

the determination step has a configuration to determine presence or absence of an obstacle for each of the plurality of detection regions.