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SENSOR, CONTROL METHOD FOR SENSOR, PROGRAM, AND SAFETY MONITORING SYSTEM

Abstract

To enhance productivity at a production site where a robot and a worker work together. A sensor includes an image generation unit configured to generate a distance image and a luminance image of a predetermined region, a first point cloud data creation unit configured to create, on the basis of the distance image, first point cloud data that is point cloud data of the predetermined region, a mask data creation unit configured to create, when a tag is detected from the luminance image, mask data for masking a predetermined range in the predetermined region on the basis of an analysis result obtained by analyzing the tag, and a second point cloud data creation unit configured to create second point cloud data by excluding point cloud data of a mobile body provided with the tag from the first point cloud data on the basis of the mask data.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION
[0001] This application claims the benefit of priority to Japanese Patent Application Number 2024-022797 filed on Feb. 19, 2024. The entire contents of the above-identified application are hereby incorporated by reference.
TECHNICAL FIELD
[0002] The present invention relates to a sensor, a sensor control method, a program, and a safety monitoring system.
BACKGROUND ART
[0003] At a production site, workers and robots carry out tasks while working together. At such a production site, efforts are made to ensure worker safety while also enhancing productivity. For example, Patent Literature 1 discloses a technique for enhancing both safety and productivity at a production site where robots and workers work together.
CITATION LIST
Patent Literature
[0004] Patent Literature 1: Japanese Patent No. 7036078
SUMMARY OF INVENTION
Technical Problem
[0005] At a production site, when a sensor detects that a person such as a worker is approaching a hazard such as a robot, the robot is decelerated or stopped. At a production site, a mobile device (mobile body) other than a person may be in operation. When an object approaching the robot is detected, the robot is decelerated or stopped regardless of whether the object is a person or a mobile device, resulting in a problem of a reduction in productivity.
[0006] The present invention has been made in view of the above problems, and an object of the present invention is to provide a technique for enhancing productivity at a production site where a robot and a worker work together.
Solution to Problem
[0007] A sensor according to an aspect of the present invention includes an image generation unit configured to generate a distance image and a luminance image of a predetermined region, a first point cloud data creation unit configured to create, on the basis of the distance image, first point cloud data that is three-dimensional point cloud data of the predetermined region, a mask data creation unit configured to create, when a tag is detected from the luminance image, mask data for masking a predetermined range in the predetermined region on the basis of an analysis result obtained by analyzing the tag, and a second point cloud data creation unit configured to create second point cloud data by excluding point cloud data of a mobile body provided with the tag from the first point cloud data on the basis of the mask data. With safety in the predetermined region being monitored using the second point cloud data obtained by excluding the point cloud data of the mobile body provided with the tag from the first point cloud data, it is possible to enhance productivity at a production site in which a robot and a worker work together.
[0008] The sensor includes an analysis unit configured to analyze the tag, and the analysis unit is configured to acquire identification information of the tag on the basis of the luminance image, acquire size data related to the mobile body on the basis of the identification information of the tag,

calculate position coordinates of the tag and angle information of the tag on the basis of the distance image and the luminance image or on the basis of the luminance image, and generate the mask data on the basis of the size data, the position coordinates of the tag, the angle information of the tag, and relationship information indicating a relative positional relationship between the tag and the mobile body. The tag has a geometric feature.

[0009] The sensor includes a determination unit configured to determine a positional relationship between a worker and a hazard in the predetermined region on the basis of the second point cloud data. The sensor includes a determination unit configured to determine, when the tag is not detected from the luminance image, a positional relationship between a worker and a hazard in the predetermined region on the basis of the first point cloud data.

[0010] The present invention can also be regarded as a control method including at least a portion of the processing described above, a program for causing a computer to execute at least a portion of the processing described above, or a computer-readable storage medium having such a program recorded in a non-transitory manner. Further, the present invention can be regarded as a safety monitoring system including at least a portion of the processing described above. The configurations and processing described above can be combined to configure the present invention as long as no technical contradiction arises.

Advantageous Effects of Invention

[0011] According to the present invention, it is possible to enhance productivity at a production site where a robot and a worker work together.

Description

BRIEF DESCRIPTION OF DRAWINGS

[0012] FIG. **1** is a schematic configuration diagram of a control system.

[0013] FIG. **2** is a block diagram illustrating a configuration of a sensor.

[0014] FIG. **3** is a flowchart describing a processing flow of the control system.

[0015] FIG. **4** is a view illustrating an example of a traveling device including a tag.

[0016] FIG. **5** is a view illustrating an example of a transport device including a tag.

[0017] FIG. **6** is a functional block diagram illustrating a configuration of a control unit.

[0018] FIG. **7** is a flowchart describing a processing flow of the control system.

[0019] FIG. **8** is a schematic configuration diagram of a control system according to a first modified example.

[0020] FIG. **9** is a functional block diagram illustrating a configuration of the control unit according to a second modified example.

[0021] FIG. **10** is a functional block diagram illustrating a configuration of a control device according to the second modified example.

DESCRIPTION OF EMBODIMENTS

[0022] Hereinafter, application examples and embodiments will be described with reference to the drawings. The application examples and embodiments described below are aspects of the present application, and do not limit the scope of rights of the present application.

Application Examples

[0023] FIG. **1** is a schematic configuration diagram of a control system (safety monitoring system). In the control system of FIG. **1**, in an environment in which a hazard such as a fixed robot **1**, a worker (person) **100**, and a mobile robot **101** work together at a production site such as a factory, for example, the fixed robot **1** is controlled while movement of the worker **100** is identified. The fixed robot **1** is, for example, a fixedly installed robot such as a vertical articulated robot, a horizontal articulated robot, or a parallel link robot. The mobile robot **101** is, for example, a traveling device such as an autonomous mobile robot (AMR) or an automated guided vehicle

(AGV). Further, the mobile robot **101** may be a transport device in which a manipulator is attached to a traveling device. In FIG. **1**, the fixed robot **1** is installed on a workbench **200**. The fixed robot **1** is controlled by a robot controller (control device) **2**. A protected region (hazardous region) **10** is set in the vicinity or surrounding area of the fixed robot **1**. The protected region **10** is a virtual three-dimensional region for detecting that an object is approaching the fixed robot **1**, and is set at least partially in the vicinity or surrounding area of the fixed robot **1**. The protected region **10** is set as the surrounding area of the fixed robot **1** in FIG. **1**, but the protected region **10** may be set as at least one of a frontward area, a rearward area, or a lateral area of the fixed robot **1**. Further, a plurality of protected regions **10** may be set. The protected region **10** is determined in accordance with safety standards, taking into account an operation range of the fixed robot **1**.

[0024] A three-dimensional safety sensor **3** (hereinafter referred to as sensor **3**) is installed at a desired position in the production site. The protected region **10** and a monitoring area can be set as desired. The monitoring area is a region to be monitored by the sensor **3**. A user may operate an information processing device **4** to set the protected region **10** and the monitoring area for the sensor **3**. The information processing device **4** is, for example, a personal computer or a tablet terminal. For example, the entire surrounding area of the protected region **10** may be set as the monitoring area, or part of the surrounding area of the protected region **10** may be set as the monitoring area. The monitoring area may be set as part of a measurement area of the sensor **3** or may be set as the entire measurement area of the sensor **3**. The measurement area of the sensor **3** is a measurable range of the sensor **3**.

[0025] The sensor **3** generates point cloud data of the monitoring area and detects whether an object has entered the protected region **10** using the point cloud data of the monitoring area. The point cloud data of the monitoring area is data indicating three-dimensional coordinates of each point of an object present in the monitoring area. When a distance between predetermined position coordinates (for example, center position coordinates) in the protected region **10** and position coordinates of an object such as a worker is equal to or less than a predetermined distance (safety distance), the sensor **3** may determine that the object has entered the protected region **10**. When entry of an object into the protected region **10** is detected by the sensor **3**, predetermined control (safety control) is performed. For example, a control signal (detection signal) is input from the sensor **3** to the robot controller **2**, and the robot controller **2** performs control for decelerating or stopping the operation of the fixed robot **1** on the basis of the control signal. The control signal may be input from the sensor **3** to an alarm device, and the alarm device may output an alert.

[0026] At a production site, a mobile body such as a traveling device or a transport device may be in operation. When the sensor **3** detects entry of a mobile body into the protected region **10** and safety control such as deceleration or stoppage of the operation of the fixed robot **1** is performed, productivity is reduced. In the control system of FIG. **1**, even if a mobile body enters the protected region **10**, safety control such as deceleration or stoppage of the operation of the fixed robot **1** is not performed. By using such a control system, it is possible to enhance productivity at a production site where the fixed robot **1** and the worker **100** work together.

[0027] FIG. **2** is a block diagram illustrating a configuration of the sensor **3**. As illustrated in FIG. **2**, the sensor **3** includes a light-emitting unit **11**, a light-receiving unit **12**, a control unit **13**, a storage unit **14**, and a communication unit **15**. The light-emitting unit **11** emits light (for example, infrared light), and the light-receiving unit **12** receives reflected light. The light-emitting unit **11** is, for example, a light-emitting diode (LED). The light-receiving unit **12** is, for example, a photodiode. As an example of the sensor **3**, a time-of-flight (TOF) sensor that acquires a distance image from the TOF of light is adopted. For example, an indirect TOF sensor that estimates a difference in time from a phase difference between emitted light and reflected light may be used as the sensor **3**.

[0028] The control unit **13** is a control device (controller) that controls the entire operation of the sensor **3**. The control unit **13** may be constituted by a dedicated device or a general-purpose computer. The control unit **13** includes hardware resources such as a processor (central processing unit (CPU)), a memory, and a storage. The memory may be a random access memory (RAM). The storage may be a nonvolatile storage device (for example, read only memory (ROM) or flash memory). A function of each processing unit (functional unit) of the control unit **13** is implemented by loading a program stored in the storage into the memory and executing the program by the processor. Note that the configuration of the control unit **13** is not limited thereto. For example, all or some of the functions of the control unit **13** may be configured by a circuit such as an application-specific integrated circuit (ASIC) or a field programmable gate array (FPGA), or all or some of the functions of the control unit **13** may be executed by a cloud server or another device.

[0029] The control unit **13** periodically generates a distance image and a luminance image. The control unit **13** measures the distance to an object (subject) by the TOF method, calculates the measured distance to a surface of the object for each pixel, and generates a distance image. The TOF method is a method of measuring a distance from a time of flight of light. The control unit **13** generates point cloud data of the monitoring area on the basis of the distance image. The control unit **13** measures an intensity of the reflected light and generates a luminance image on the basis of the intensity of the reflected light. The control unit **13** accesses a database (DB) **21** of an external device **20** to acquire information and data from the database **21**. The storage unit **14** stores the information and the data. The storage unit **14** may include at least one of a memory or a storage. The communication unit **15** is an interface for performing wired or wireless communication.

[0030] FIG. **3** is a flowchart describing a processing flow of the control system. The processing flow of the control system will now be described with reference to the flowchart of FIG. **3**. In step S**101**, the control unit **13** determines whether a tag (marker) is detectable from the luminance image. The tag has a geometric feature. A geometric pattern composed of two colors (for example, white and black) having different brightnesses may be formed on the tag. The tag is, for example, an April Tag, but is not limited thereto, and may be another geometric tag.

[0031] When the tag is detectable from the luminance image (S**101**: YES), the processing proceeds to step S**102**. When the tag is not detectable from the luminance image (S**101**: NO), the processing proceeds to step S**108**. When the tag is not reliably detectable, the control unit **13** determines that the tag is not detectable from the luminance image. For example, when an outer shape of the tag can be recognized in the luminance image, but the content of the tag cannot be analyzed, the control unit **13** may determine that the tag is not detectable from the luminance image.

[0032] The tag is provided on a traveling device or a transport device. FIG. **4** is a view illustrating an example of a traveling device **32** including a tag **31**. In the example illustrated in FIG. **4**, the tag **31** is attached to a front surface of a housing of the traveling device **32**. The location of the tag **31** is not limited to the example illustrated in FIG. **4**, and the tag **31** may be attached to a side surface or a back surface of the housing of the traveling device **32**. Further, a plurality of the tags **31** may be attached to a plurality of locations of the housing of the traveling device **32**. When the outer shape of the tag **31** of the traveling device **32** can be recognized in the luminance image, but the content of the tag **31** cannot be analyzed, the control unit **13** may communicate with the traveling device **32** via the communication unit **15** and output an instruction signal to the traveling device **32**. An instruction signal for instructing the traveling device **32** to move so that the tag **31** faces the front of the sensor **3** may be output.

[0033] FIG. **5** is a view illustrating an example of a transport device **33** including the tag **31**. The transport device **33** includes a traveling device **34** and a manipulator **35**. In the example illustrated in FIG. **5**, the tag **31** is provided on a front surface of a housing of the traveling device **34**. The location of the tag **31** is not limited to the example illustrated in FIG. **5**, and the tag **31** may be attached to a side surface or a back surface of the housing of the traveling device **34**. Further, a plurality of the tags **31** may be attached to the housing of the traveling device **34**. The tag **31** may be attached to the manipulator **35**, or a plurality of the tags **31** may be attached to the manipulator **35**. When the outer shape of the tag **31** of the transport device **33** can be recognized in the luminance image, but the content of the tag **31** cannot be analyzed, the control unit **13** may communicate with the transport device **33** via the communication unit **15** and output an instruction signal to the transport device **33**. An instruction signal for instructing the transport device **33** to move so that the tag **31** faces the front of the sensor **3** may be output. An instruction signal for instructing the manipulator **35** to move so that the tag **31** faces the front of the sensor **3** may be output.

[0034] In step S**102**, the control unit **13** acquires identification (ID) information by reading the geometric pattern of the tag in the luminance image. The ID information is unique identification information that does not overlap, and is different for each mobile body. The mobile body is an example of a traveling device and a transport device.

[0035] In step S**103**, the control unit **13** calculates position coordinates (x, y, z) of the tag and angle information of the tag on the basis of the luminance image and the distance image. The position coordinates of the tag are, for example, coordinates (x, y, z) of the tag in a camera coordinate system. The position coordinates of the tag may be coordinates of a center of the tag. The angle information of the tag includes an angle with respect to a reference plane (horizontal plane, ground) and an angle with respect to a plane orthogonal to the reference plane. In step S**103**, the control unit **13** acquires the reference coordinates stored in the storage unit **14**. The reference coordinates are relationship information indicating a relative positional relationship between the tag and the mobile body. The reference coordinates are, for example, coordinates (x, y, z) indicating an installation position of the tag with respect to the mobile body, and a position of a predetermined area (for example, corner portion) of the mobile body may be set as the origin. In step S**103**, the control unit **13** may calculate the position coordinates of the tag and the angle information of the tag on the basis of the luminance image.

[0036] In step S**104**, the control unit **13** acquires size data of the mobile body from the database **21** on the basis of the ID information. The database **21** stores the ID information and the size data in association with each other. The size data of the mobile body may include data related to values of dimensions (vertical width, horizontal width, and height) of the mobile body or may include data related to values obtained by adding a margin to the dimensions of the mobile body.

[0037] In step S**105**, the control unit **13** generates point cloud range data of the mobile body on the basis of the size data of the mobile body, the position coordinates of the tag, the angle information of the tag, and the reference coordinates. The tag is provided on the mobile body. The control unit **13** calculates position coordinates (x, y, z) of the mobile body on the basis of the position coordinates of the tag, the reference coordinates, and the size data of the mobile body. The control unit **13** may calculate coordinates at a center of the mobile body as the position coordinates of the mobile body. The tag provided on the mobile body is inclined in accordance with the angle information of the mobile body (information related to a direction in which the mobile body faces), and thus the angle information of the tag differs for each set of angle information of the mobile body. The control unit **13** calculates the angle information of the mobile body on the basis of the angle information of the tag. The control unit **13** generates the point cloud range data of the mobile body on the basis of the position coordinates of the mobile body, the angle information of the mobile body, and the size data of the mobile body. The point cloud range data of the mobile body is mask data for masking a predetermined range in the monitoring area, and is data indicating a range in which the mobile body is present in the monitoring area. That is, the point cloud range data of the mobile body is data indicating a range occupied by the point cloud data of the mobile body in the point cloud data of the monitoring area.

[0038] In step S**106**, the control unit **13** excludes (deletes) the point cloud data of the mobile body from the point cloud data of the monitoring area on the basis of the point cloud range data of the mobile body, thereby invalidating (masking) the point cloud data of the mobile body in the point cloud data of the monitoring area. Hereinafter, the point cloud data obtained by excluding the point cloud data of the mobile body from the point cloud data of the monitoring area is referred to as

point cloud data after masking.
[0039] In step S**107**, the control unit **13** performs safety monitoring on the basis of the point cloud data after masking. For example, the control unit **13** performs safety monitoring by determining whether an object such as the worker **100** has entered the protected region **10**.
[0040] In step S**108**, the control unit **13** performs safety monitoring on the basis of the point cloud data of the monitoring area. A tag is not detected from the luminance image, and thus the control unit **13** treats the object in the monitoring area as a person.
[0041] According to the embodiment, the control unit **13** performs safety monitoring on the basis of the point cloud data after masking and thus, even if a mobile body enters the protected region **10**, does not perform safety control such as deceleration or stoppage of the operation of the fixed robot **1**. Thus, by not performing the safety control when the mobile body has entered the protected region **10**, it is possible to enhance productivity at a production site where the fixed robot **1** and the worker **100** work together.
[0042] Preferably, the tag is provided on the mobile body in a way that facilitates detection of the tag from the luminance image. For example, when the sensor **3** is attached above the monitoring area, the tag may be provided on the mobile body so that the tag faces upward. For example, when the sensor **3** is installed facing obliquely downward, the tag may be provided on the mobile body so that the tag faces obliquely upward.
[0043] FIG. **6** is a functional block diagram illustrating a configuration of the control unit **13**. The control unit **13** includes an image generation unit **110**, a first point cloud data creation unit **120**, a detection unit **130**, an analysis unit **140**, a mask data creation unit **150**, a second point cloud data creation unit **160**, a determination unit **170**, and an output unit **180**. The image generation unit **110** generates a distance image and a luminance image of a predetermined region. The predetermined region may be, for example, the monitoring area. The first point cloud data creation unit **120** creates first point cloud data that is the point cloud data of the predetermined region. The detection unit **130** detects a tag from the luminance image. When a tag is detected from the luminance image, the analysis unit **140** analyzes the detected tag. The mask data creation unit **150** creates mask data for masking a predetermined range in the predetermined region on the basis of the analysis result obtained by analyzing the tag by the analysis unit **140**. The second point cloud data creation unit **160** creates second point cloud data by excluding the point cloud data of the mobile body from the first point cloud data on the basis of the mask data. The determination unit **170** determines the positional relationship between the worker **100** and a hazard such as the fixed robot **1** in the predetermined region. The output unit **180** outputs a predetermined signal.
[0044] An example of processing performed by the analysis unit **140** when a tag has a geometric feature will now be described. The analysis unit **140** acquires identification (ID) information of the tag on the basis of the luminance image. The geometric feature of the tag is, for example, a geometric pattern provided on the tag. In the storage unit **14**, the geometric feature of the tag and the ID information of the tag are stored in association with each other. The analysis unit **140** analyzes the luminance image and extracts the geometric feature of the tag in the luminance image. The analysis unit **140** acquires the ID information of the tag from the geometric feature of the tag in the luminance image. The analysis unit **140** acquires the size data of the mobile body from the database **21** on the basis of the ID information of the tag. The ID information and the size data may be stored in the storage unit **14** in association with each other. The analysis unit **140** may acquire the size data of the mobile body from the storage unit **14**. The analysis unit **140** calculates the position coordinates of the tag, the angle information of the tag, and the reference coordinates on the basis of the distance image and the luminance image. The mask data creation unit **150** generates point cloud range data (mask data) of the mobile body on the basis of the size data of the mobile body, the position coordinates of the tag, the angle information of the tag, and the reference coordinates.
[0045] When the tag is detected from the luminance image, the determination unit **170** determines

the positional relationship between the worker **100** and the hazard such as the fixed robot **1** in the predetermined region on the basis of the second point cloud data. The determination unit **170** may determine whether a distance between the position coordinates of the worker **100** and the predetermined position coordinates (center position coordinates of the hazard such as the fixed robot **1**) in the predetermined region is equal to or less than a predetermined distance on the basis of the second point cloud data. When the tag is not detected from the luminance image, the determination unit **170** determines the positional relationship between the worker **100** and the hazard such as the fixed robot **1** in the predetermined region on the basis of the first point cloud data. The determination unit **170** may determine whether the distance between the position coordinates of the worker **100** and the predetermined position coordinates in the predetermined region is equal to or less than the predetermined distance on the basis of the first point cloud data. When the distance between the position coordinates of the worker **100** and the predetermined position coordinates in the predetermined region is equal to or less than the predetermined distance, the output unit **180** outputs a control signal (detection signal) to the robot controller **2**. The robot controller **2** performs control for decelerating or stopping the operation of the fixed robot **1** on the basis of the control signal.

[0046] Although a tag having a geometric feature is used in the above description, the tag is not limited thereto, and a tag including a character string, a number string, or a combination of characters and numbers indicating identification (ID) information may be used. FIG. **7** is a flowchart describing a processing flow of the control system when a tag including ID information is used. The processing flow of the control system when a tag including ID information is used will now be described with reference to the flowchart of FIG. **7**.

[0047] In step S**201**, the control unit **13** determines whether a tag is detectable from the luminance image. The tag includes a character string, a number string, or a combination of characters and numbers indicating the ID information of the tag. For example, a character string, a number string, or a combination of characters and numbers indicating the ID information of the tag may be displayed on a front surface of the tag. When the tag can be extracted from the luminance image (S**201**: YES), the processing proceeds to step S**202**. When the tag cannot be extracted from the luminance image (S**201**: NO), the processing proceeds to step S**208**. When the tag is not reliably detectable, the control unit **13** determines that the tag is not detectable from the luminance image. For example, when the outer shape of the tag can be recognized in the luminance image, but the content of the tag cannot be analyzed, the control unit **13** may determine that the tag is not detectable from the luminance image.

[0048] In step S**202**, the control unit **13** acquires the ID information by reading the ID information of the tag in the luminance image. The ID information is unique identification information that does not overlap, and is different for each mobile body.

[0049] In step S**203**, the control unit **13** calculates the position coordinates (x, y, z) of the tag on the basis of the luminance image and the distance image. In step S**203**, the control unit **13** acquires the angle information of the mobile body from the mobile body via the communication unit **15**. The angle information of the mobile body may include an angle of the mobile body in a planar direction or may include a direction in which the mobile body faces. For example, the mobile body may calculate the angle information of the mobile body by performing self-position estimation processing on the basis of map data of the production site and a landmark arranged at the production site. Alternatively, in step S**203**, the control unit **13** may calculate the angle information of the mobile body by recognizing a shape of the mobile body on the basis of the distance image and the luminance image.

[0050] In step S**204**, the control unit **13** acquires the size data of the mobile body from the database **21** on the basis of the ID information. The database **21** stores the ID information and the size data in association with each other. The size data of the mobile body may include data related to values of dimensions (vertical width, horizontal width, and height) of the mobile body or may include data related to values obtained by adding a margin to the dimensions of the mobile body. The control unit **13** may acquire the size data of the mobile body using a result of recognition of the shape of the mobile body on the basis of the distance image and the luminance image.

[0051] In step S**205**, the control unit **13** generates the point cloud range data of the mobile body on the basis of the size data of the mobile body, the position coordinates of the tag, and the angle information of the mobile body. The tag is provided on the mobile body. The control unit **13** may calculate the position coordinates (x, y, z) of the mobile body on the basis of the position coordinates of the tag. The control unit **13** may calculate the position coordinates of the tag as the position coordinates of the mobile body. The control unit **13** may calculate the position coordinates of the mobile body on the basis of the position coordinates of the tag and the size data of the mobile body. The control unit **13** generates the point cloud range data of the mobile body on the basis of the position coordinates of the mobile body, the angle information of the mobile body, and the size data of the mobile body. The point cloud range data of the mobile body is mask data for masking a predetermined range in the monitoring area, and is data indicating a range in which the mobile body is present in the monitoring area. That is, the point cloud range data of the mobile body is data indicating a range occupied by the point cloud data of the mobile body in the point cloud data of the monitoring area.

[0052] In step S**206**, the control unit **13** excludes (deletes) the point cloud data of the mobile body from the point cloud data of the monitoring area on the basis of the point cloud range data of the mobile body, thereby invalidating (masking) the point cloud data of the mobile body in the point cloud data of the monitoring area. Hereinafter, the point cloud data obtained by excluding the point cloud data of the mobile body from the point cloud data of the monitoring area is referred to as point cloud data after masking.

[0053] In step S**207**, the control unit **13** performs safety monitoring on the basis of the point cloud data after masking. For example, the control unit **13** performs safety monitoring by determining whether an object such as the worker **100** has entered the protected region **10**.

[0054] In step S**208**, the control unit **13** performs safety monitoring on the basis of the point cloud data of the monitoring area. A tag is not detected from the luminance image, and thus the control unit **13** treats the object in the monitoring area as a person.

[0055] An example of the processing of the analysis unit **140** when a tag includes a character string, a number string, or a combination of characters and numbers indicating identification (ID) information of the tag will now be described. The analysis unit **140** analyzes the luminance image. The analysis unit **140** acquires identification (ID) information of the tag on the basis of the luminance image. The analysis unit **140** acquires the size data of the mobile body from the database **21** on the basis of the ID information of the tag. The ID information and the size data may be stored in the storage unit **14** in association with each other. The analysis unit **140** may acquire the size data of the mobile body from the storage unit **14**. The analysis unit **140** calculates the position coordinates of the tag on the basis of the distance image and the luminance image. The analysis unit **140** acquires the angle information of the mobile body from the mobile body via the communication unit **15**. The mask data creation unit **150** generates the point cloud range data (mask data) of the mobile body on the basis of the size data of the mobile body, the position coordinates of the tag, and the angle information of the mobile body.

[0056] The present embodiment can also be applied to a two-dimensional laser scanner. The distance image may be generated by the two-dimensional laser scanner, a camera may be separately provided, the luminance image may be generated by the camera, and the luminance image may be transmitted to the two-dimensional laser scanner.

First Modified Example

[0057] A modified example will now be described. FIG. **8** is a schematic configuration diagram of a control system (safety monitoring system) according to a first modified example. In the control system illustrated in FIG. **8**, an interference prevention region **40** is set in addition to the control system illustrated in FIG. **1**. The interference prevention region **40** is a region for preventing interference between the fixed robot **1** and the mobile robot **101**. The interference prevention region **40** is a virtual three-dimensional region for detecting that the mobile robot **101** is approaching the fixed robot **1**, and is set at least partially in the vicinity or surrounding area of the fixed robot **1**. In the example illustrated in FIG. **8**, the interference prevention region **40** is set in a range narrower than that of the protected region **10**, but is not limited to this example, and the interference prevention region **40** may be set in the same range as that of the protected region **10**, or may be set in a range wider than that of the protected region **10**. Further, the interference prevention region **40** is set in the area surrounding the fixed robot **1** in FIG. **8**, but the interference prevention region **40** may be set in at least one of the frontward area, the rearward area, or the lateral area of the fixed robot **1**. Further, a plurality of the interference prevention regions **40** may be set. The user may operate the information processing device **4** to set the interference prevention region **40** for the sensor **3**.

[0058] The sensor **3** generates the point cloud data of the monitoring area and detects whether the mobile robot **101** has entered the interference prevention region **40** using the point cloud data of the monitoring area. When a distance between predetermined position coordinates (for example, center position coordinates) in the interference prevention region **40** and the position coordinates of the mobile robot **101** is equal to or less than a predetermined distance (interference distance), the sensor **3** may determine that the mobile robot **101** has entered the interference prevention region **40**. When the sensor **3** detects the entry of the mobile robot **101** into the interference prevention region **40**, predetermined control (safety control) is performed. For example, a control signal (interference flag) is input from the sensor **3** to the robot controller **2**, and the robot controller **2** performs control for decelerating or stopping the operation of the fixed robot **1** on the basis of the control signal.

Second Modified Example

[0059] A second modified example will now be described. FIG. **9** is a functional block diagram illustrating a configuration of the control unit **13** according to a second modified example. The control unit **13** includes the determination unit **170**, the output unit **180**, and an image acquisition unit **190**. The image acquisition unit **190** acquires the distance image and the luminance image of the predetermined region. The image acquisition unit **190** may generate the distance image and the luminance image of the predetermined region. The image acquisition unit **190** may generate the distance image of the predetermined region or may acquire the luminance image from another sensor (camera).

[0060] The control system according to the second modified example may include a control device **300**. FIG. **10** is a functional block diagram illustrating a configuration of the control device **300** according to the second modified example. The control device **300** may be, for example, an information processing device such as a personal computer or a tablet terminal. The control device **300** may be constituted by a dedicated device or may be constituted by a general-purpose computer. The control device **300** includes hardware resources such as a processor (CPU), a memory, and a storage. A function of each processing unit (functional unit) of the control device **300** is implemented by loading a program stored in the storage into the memory and executing the program by the processor. Note that the configuration of the control device **300** is not limited thereto. For example, all or some of the functions of the control device **300** may be configured by a circuit such as an ASIC or a FPGA, or all or some of the functions of the control device **300** may be executed by a cloud server or another device. The control device **300** includes a communication unit that is an interface for performing wired or wireless communication. Communication is performed between the control unit **13** and the control device **300**.

[0061] The control device **300** includes a first point cloud data creation unit **310**, a detection unit **320**, an analysis unit **330**, a mask data creation unit **340**, and a second point cloud data creation unit **350**. The first point cloud data creation unit **310** creates first point cloud data that is point cloud data of the predetermined region. The detection unit **320** detects a tag from the luminance image. When a tag is detected from the luminance image, the analysis unit **330** analyzes the detected tag. The mask data creation unit **340** creates mask data for masking a predetermined range in the predetermined region on the basis of the analysis result obtained by analyzing the tag by the analysis unit **330**. The second point cloud data creation unit **350** creates second point cloud data by excluding the point cloud data of the mobile body from the first point cloud data on the basis of the mask data. The processing executed by the first point cloud data creation unit **310**, the detection unit **320**, the analysis unit **330**, the mask data creation unit **340**, and the second point cloud data creation unit **350** is the same as the processing executed by the first point cloud data creation unit **120**, the detection unit **130**, the analysis unit **140**, the mask data creation unit **150**, and the second point cloud data creation unit **160**.

[0062] In the second modified example, the control device **300** may execute the processing of steps S**101** to S**106** in FIG. **3**, and the control unit **13** may execute the processing of steps S**107** and S**108** in FIG. **3**. In the second modified example, the control device **300** may execute the processing of steps S**201** to S**206** in FIG. **7**, and the control unit **13** may execute the processing of steps S**207** and S**208** in FIG. **7**. The control unit **13** according to the second modified example may include at least one of the first point cloud data creation unit **120**, the detection unit **130**, the analysis unit **140**, the mask data creation unit **150**, or the second point cloud data creation unit **160**. In the second modified example, the control unit **13** and the control device **300** may share and execute the processing of steps S**101** to S**106** in FIG. **3**. Further, in the second modified example, the control unit **13** and the control device **300** may share and execute the processing of steps S**201** to S**206** of FIG. **7**.

Third Modified Example

[0063] A third modified example will now be described. The sensor **3** may acquire a movement range of the mobile robot **101** and determine whether part of the movement range of the mobile robot **101** and part of the protected region **10** overlap. The sensor **3** may acquire the movement range of the mobile robot **101** from the mobile robot **101**. The sensor **3** may acquire the movement range of the mobile robot **101** from an upper device that manages the movement range of the mobile robot **101**. When part of the movement range of the mobile robot **101** and part of the protected region **10** overlap, a control signal (interference flag) may be input from the sensor **3** to the robot controller **2**. The robot controller **2** may perform control for decelerating or stopping the operation of the fixed robot **1** on the basis of the control signal. When part of the movement range of the mobile robot **101** and part of the protected region **10** overlap, the sensor **3** may issue an instruction for changing the movement range of the mobile robot **101** (movement range change instruction). A control signal for the movement range change instruction may be input from the sensor **3** to the mobile robot **101**. The control signal for the movement range change instruction may be input to the mobile robot **101** from an upper device. When the control signal for the movement range change instruction is input to the mobile robot **101**, the movement range of the mobile robot **101** is changed. For example, the movement range of the mobile robot **101** is narrowed, changing the movement range of the mobile robot **101** so that the movement range of the mobile robot **101** and the protected region **10** do not overlap. This suppresses interference between the operation of the fixed robot **1** and the movement of the mobile robot **101**. Accordingly, it is possible to avoid frequent performance of safety control and enhance productivity.

[0064] In the third modified example, the sensor **3** may determine whether part of the movement range of the mobile robot **101** and part of the interference prevention region **40** in the first modified example overlap. When part of the movement range of the mobile robot **101** and part of the interference prevention region **40** overlap, a control signal (interference flag) may be input from the sensor **3** to the robot controller **2**. The robot controller **2** may perform control for decelerating or stopping the operation of the fixed robot **1** on the basis of the control signal. When part of the movement range of the mobile robot **101** and part of the interference prevention region **40** overlap, the sensor **3** may issue the movement range change instruction. Changing the movement range of the mobile robot **101** suppresses interference between the operation of the fixed robot **1** and the movement of the mobile robot **101**. Accordingly, it is possible to avoid frequent performance of safety control and enhance productivity.

<Computer-Readable Recording Medium>

[0065] A program for causing an information processing device or any other machine or device (hereinafter referred to as a computer or the like) to implement any of the functions described above may be recorded in a recording medium readable by the computer or the like. The functions can be provided by causing the computer or the like to load the program from the recording medium and to execute the program.

[0066] Here, the recording medium readable by the computer or the like refers to a recording medium capable of storing information such as data or programs by an electrical, magnetic, optical, mechanical, or chemical action in such a manner that the computer or the like can read the information from the recording medium. Among such recording media, those which can be removed from the computer or the like include, for example, flexible disks, magneto-optical discs, CD-ROMs, CD-R/Ws, DVDs, Blu-ray discs, and flash memories. Recording media fixed to the computer or the like include hard disks and ROMs.

Supplementary Note 1

A sensor (**3**) including [0067] an image generation unit (**110**) configured to generate a distance image and a luminance image of a predetermined region; [0068] a first point cloud data creation unit (**120**) configured to create, on the basis of the distance image, first point cloud data that is three-dimensional point cloud data of the predetermined region; [0069] a mask data creation unit (**150**) configured to create, when a tag is detected from the luminance image, mask data for masking a predetermined range in the predetermined region on the basis of an analysis result obtained by analyzing the tag; and [0070] a second point cloud data creation unit (**160**) configured to create second point cloud data by excluding point cloud data of a mobile body provided with the tag from the first point cloud data on the basis of the mask data.

Supplementary Note 2

The sensor (**3**) according to Supplementary Note 1, including [0071] an analysis unit (**140**) configured to analyze the tag, wherein the analysis unit (**140**) is configured to [0072] acquire identification information of the tag on the basis of the luminance image, acquire size data related to the mobile body on the basis of the identification information of the tag, [0073] calculate position coordinates of the tag and angle information of the tag on the basis of the distance image and the luminance image or on the basis of the luminance image, and [0074] generate the mask data on the basis of the size data, the position coordinates of the tag, the angle information of the tag, and relationship information indicating a relative positional relationship between the tag and the mobile body.

Supplementary Note 3

The sensor (**3**) according to Supplementary Note 2, wherein [0075] the tag has a geometric feature.

Supplementary Note 4

The sensor (**3**) according to any one of Supplementary Notes 1 to 3, including a determination unit configured to determine a positional relationship between a worker and a hazard in the predetermined region on the basis of the second point cloud data.

Supplementary Note 5

The sensor (**3**) according to any one of Supplementary Notes 1 to 3, including a determination unit configured to determine, when the tag is not detected from the luminance image, a positional relationship between a worker and a hazard in the predetermined region on the basis of the first point cloud data.

Supplementary Note 6

A method for controlling the sensor (**3**), the method including: [0076] generating a distance image

and a luminance image of a predetermined region; [0077] creating, on the basis of the distance image, first point cloud data that is three-dimensional point cloud data of the predetermined region; [0078] creating, when a tag is detected from the luminous image, mask data for masking a predetermined range in the predetermined region on the basis of an analysis result obtained by analyzing the tag; and [0079] creating second point cloud data by excluding point cloud data of a mobile body provided with the tag from the first point cloud data on the basis of the mask data.
Supplementary Note 7
A program for causing a computer to execute [0080] generating a distance image and a luminance image of a predetermined region; [0081] creating, on the basis of the distance image, first point cloud data that is three-dimensional point cloud data of the predetermined region; [0082] creating, when a tag is detected from the luminous image, mask data for masking a predetermined range in the predetermined region on the basis of an analysis result obtained by analyzing the tag; and [0083] creating second point cloud data by excluding point cloud data of a mobile body provided with the tag from the first point cloud data on the basis of the mask data.
Supplementary Note 8
A safety monitoring system including [0084] an image acquisition unit (**190**) configured to acquire a distance image and a luminance image of a predetermined region; [0085] a first point cloud data creation unit (**310**) configured to create, on the basis of the distance image, first point cloud data that is three-dimensional point cloud data of the predetermined region; [0086] a mask data creation unit (**340**) configured to create, when a tag is detected from the luminance image, mask data for masking a predetermined range in the predetermined region on the basis of an analysis result obtained by analyzing the tag; and [0087] a second point cloud data creation unit (**350**) configured to create second point cloud data by excluding point cloud data of a mobile body provided with the tag from the first point cloud data on the basis of the mask data.
REFERENCE SIGNS LIST
[0088] **1**: Fixed robot [0089] **2**: Robot controller [0090] **3**: Three-dimensional safety sensor [0091] **4**: Information processing device [0092] **10**: Protected region [0093] **11**: Light-emitting unit [0094] **12**: Light-receiving unit [0095] **13**: Control unit [0096] **14**: Storage unit [0097] **15**: Communication unit [0098] **20**: External device [0099] **21**: Database [0100] **31**: Tag [0101] **32**, **34**: Traveling device [0102] **33**: Transport device [0103] **34**: Traveling device [0104] **35**: Manipulator [0105] **40**: Interference prevention region [0106] **100**: Worker [0107] **101**: Mobile robot [0108] **110**: Image generation unit [0109] **120**, **310**: First point cloud data creation unit [0110] **130**, **320**: Detection unit [0111] **140**, **330**: Analysis unit [0112] **150**, **340**: Mask data creation unit [0113] **160**, **350**: Second point cloud data creation unit [0114] **170**: Determination unit [0115] **180**: Output unit [0116] **300**: Control device

Claims

1. A sensor comprising: an image generation unit configured to generate a distance image and a luminance image of a predetermined region; a first point cloud data creation unit configured to create, on the basis of the distance image, first point cloud data that is three-dimensional point cloud data of the predetermined region; a mask data creation unit configured to create, when a tag is detected from the luminance image, mask data for masking a predetermined range in the predetermined region on the basis of an analysis result obtained by analyzing the tag; and a second point cloud data creation unit configured to create second point cloud data by excluding point cloud data of a mobile body provided with the tag from the first point cloud data on the basis of the mask data.
2. The sensor according to claim 1, comprising an analysis unit configured to analyze the tag, wherein the analysis unit is configured to acquire identification information of the tag on the basis of the luminance image, acquire size data related to the mobile body on the basis of the

identification information of the tag, calculate position coordinates of the tag and angle information of the tag on the basis of the distance image and the luminance image or on the basis of the luminance image, and generate the mask data on the basis of the size data, the position coordinates of the tag, the angle information of the tag, and relationship information indicating a relative positional relationship between the tag and the mobile body.

3. The sensor according to claim 2, wherein the tag has a geometric feature.

4. The sensor according to claim 1, comprising a determination unit configured to determine a positional relationship between a worker and a hazard in the predetermined region on the basis of the second point cloud data.

5. The sensor according to claim 1, comprising a determination unit configured to determine, when the tag is not detected from the luminance image, a positional relationship between a worker and a hazard in the predetermined region on the basis of the first point cloud data.

6. A method for controlling a sensor, the method comprising: generating a distance image and a luminance image of a predetermined region; creating, on the basis of the distance image, first point cloud data that is three-dimensional point cloud data of the predetermined region; creating, when a tag is detected from the luminance image, mask data for masking a predetermined range in the predetermined region on the basis of an analysis result obtained by analyzing the tag; and creating second point cloud data by excluding point cloud data of a mobile body provided with the tag from the first point cloud data on the basis of the mask data.

7. A non-transitory computer readable medium storing program for causing a computer to execute the generating and the creating in the method according to claim 6.

8. A safety monitoring system comprising: an image acquisition unit configured to acquire a distance image and a luminance image of a predetermined region; a first point cloud data creation unit configured to create, on the basis of the distance image, first point cloud data that is three-dimensional point cloud data of the predetermined region; a mask data creation unit configured to create, when a tag is detected from the luminance image, mask data for masking a predetermined range in the predetermined region on the basis of an analysis result obtained by analyzing the tag; and a second point cloud data creation unit configured to create second point cloud data by excluding point cloud data of a mobile body provided with the tag from the first point cloud data on the basis of the mask data.