

TITLE OF THE INVENTION

TARGET IDENTIFICATION SYSTEM AND TARGET
IDENTIFICATION METHOD

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001]

The present invention relates to a target identification system and a target identification method.

2. Description of the Related Art

[0002]

During maintenance and inspection of equipment such as a server, a worker engaged in the maintenance and inspection occasionally conducts pointing and calling at a target. When conducting pointing and calling, the worker thrusts an arm forward, points a fingertip to the target, and verbally calls out the status of the target.

[0003]

Disclosed in JP-2016-224890-A is an information processing apparatus that uses an imaging unit attached to a worker in order to capture an image depicting a target and a fingertip of the worker who is apart from and points at the target, and identifies a pointed location intended by the worker within the captured image.

SUMMARY OF THE INVENTION

[0005]

Where a camera is attached to the body of the worker engaged in maintenance and inspection, an image captured by the camera enables determination of whether the worker is conducting pointing and calling and determination of the target pointed at by the worker. However, parallax occurs between the line of sight of the worker and the orientation of the camera attached to the worker. Therefore, at a viewing angle (in a field of vision) of the worker pointing and calling, the fingertip of the worker and the target do not overlap in the image captured by the camera attached to the worker even in a case where the fingertip of the worker overlaps with the target. As described above, the target pointed at by the worker cannot easily be identified from the image captured by the camera.

[0006]

In view of the above circumstances, the present invention provides a technology for properly identifying the target on the basis of the image captured by an imaging unit attached to the worker.

[0007]

In order to provide the above-mentioned

technology, according to an aspect of the present invention, there is provided a target identification system that identifies a target pointed at by a worker, on the basis of an image captured by an imaging unit attached to the worker. The target identification system includes a calculation section, a creation section, a setting section, an estimation section, and an identification section. The calculation section calculates a positional relation between eyes of the worker and the imaging unit on the basis of a reference image that is captured by the imaging unit while the worker confronts a reference target placed at a predetermined distance. The creation section creates an environmental map of a space imaged by the imaging unit, on the basis of a spatial image captured by the imaging unit. The setting section sets a line-of-sight plane on the basis of the positional relation. The line-of-sight plane contains the target and the eyes and fingertip of the worker in the environmental map. The estimation section estimates a line of sight of the worker in the line-of-sight plane on the basis of coordinate difference between central coordinates and the fingertip in a predetermined image that is captured by the imaging unit to depict the fingertip and the target while the target is pointed at by the worker. The identification section

identifies the target pointed at by the worker, on a basis of the line of sight.

It should be noted that the imaging unit attached to the worker may alternatively be attached, for example, to a helmet worn by the worker.

[0008]

The technology provided by the present invention is capable of properly identifying the target on the basis of the image captured by the imaging unit attached to the worker.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

FIG. 1 is a schematic diagram illustrating a target identification system for a work site according to a first embodiment of the present invention;

FIG. 2 is a diagram illustrating a comparison between a camera image and a field of vision of a worker according to the first embodiment;

FIGS. 3A and 3B are diagrams each illustrating the position of a fingertip of a worker pointing and calling according to the first embodiment;

FIG. 4 is a functional block diagram illustrating the target identification system according to the first embodiment;

FIGS. 5A to 5D are diagrams illustrating a target identification process according to the first embodiment;

FIG. 6 is a schematic diagram illustrating an approach distance according to the first embodiment;

FIG. 7 is a diagram illustrating the screen of a display device according to the first embodiment;

FIG. 8 is a schematic diagram illustrating a calibration according to the first embodiment;

FIG. 9 is a diagram illustrating parallax that is calculated from the calibration according to the first embodiment;

FIG. 10 is a flowchart illustrating the target identification process according to the first embodiment;

FIG. 11 is a diagram illustrating the target identification system for a work site according to a second embodiment of the present invention;

FIG. 12 is a flowchart illustrating the target identification process according to the second embodiment; and

FIG. 13 is a diagram illustrating the target identification system for a work site according to a third embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0010]

Specific examples of a target identification system according to embodiments of the present invention will now be described with reference to the accompanying drawings. It should be noted that the present invention is not limited by the embodiments described below, but is defined by the appended claims.

[First Embodiment]

[0011]

FIG. 1 is a schematic diagram illustrating a target identification system for a work site according to a first embodiment of the present invention.

[0012]

The target identification system 10 identifies a target T that is pointed at by a worker W. The target T is, for example, a server or other equipment or a facility. The worker W engaged in the maintenance and inspection of the target T conducts pointing at and calling the target T. When conducting pointing and calling, the worker W thrusts an arm forward, points a fingertip F to the target T, and verbally calls out the status of the target T.

[0013]

A helmet H is worn on the head of the worker W. A camera 11 of a monocular type is mounted on the top front of the helmet H. The camera 11 serves as an

example of an "imaging unit" that is included in the target identification system 10. The camera 11 may alternatively be mounted on any part of the body of the worker T other than the head, such as a chest. Further, components of the target identification system 10 other than the camera 11 may be mounted integrally with the camera 11 or mounted in a pocket of the worker W or at a different location in such a manner as to enable the components to wirelessly or wiredly communicate with the camera 11.

[0014]

Here, it is assumed that the camera 11 is attached to the helmet H worn by the worker W and is positioned above a line of sight L1 of the worker W. The orientation L2 of the camera 11 is fixed in such a manner as to orient the camera 11 diagonally downward. Therefore, parallax θ occurs between the line of sight L1 of the worker W and the orientation L2 of the camera 11.

[0015]

FIG. 2 is a diagram illustrating a comparison between a camera image and a field of vision of the worker according to the first embodiment.

[0016]

At a viewing angle (in the field of vision) V of the worker W pointing at and calling the target T, the

fingertip F and the target T overlap at the center of the viewing angle V. However, a captured image i1 of the worker W pointing at and calling the target T, which is captured by the camera 11 as an example of a "predetermined image," depicts the fingertip F in the center of the captured image i1 and depicts the target T in the upper part of the captured image i1. The position difference (misalignment) between the fingertip F and the target T, which are depicted in the captured image i1, is proportional to the magnitude of parallax θ between the line of sight L1 of the worker W and the orientation L2 of the camera 11 and proportional to the distance between the camera 11 and the target T. In the present embodiment, the camera 11 is positioned above the line of sight L1 of the worker W. Therefore, the target T is depicted in the upper part of the captured image i1.

[0017]

FIGS. 3A and 3B are diagrams each illustrating the position of the fingertip of the worker pointing and calling according to the first embodiment. Depicted in FIG. 3A is a state where the fingertip of the worker is on the line of sight. Depicted in FIG. 3B is a state where the fingertip of the worker is positioned to the left of the line of sight.

[0018]

In general, when the worker W conducts pointing and calling, the fingertip F of the worker W is positioned near the vertical center of the viewing angle V of the worker W. More specifically, when the worker W or the action of the worker W (the angle at which the arm is bent) changes for each pointing and calling, the fingertip F of the worker W pointing at and calling the target T is positioned somewhere near the vertical center of the viewing angle V of the worker W.

[0019]

FIG. 4 is a functional block diagram illustrating the target identification system 10 according to the first embodiment. FIGS. 5A to 5D are diagrams illustrating a target identification process according to the first embodiment.

[0020]

The target identification system 10 performs the target identification process of identifying the target T pointed at by the worker W. The target identification system 10 includes the camera 11 of a monocular type, a memory 12 serving as an example of a "storage section," a processor 13, a warning section 14, and a display section 15.

[0021]

The camera 11 is attached to the helmet H worn by

the worker W and used to capture an image of the target T. The camera 11 transmits the captured image i1 of the target T to the processor 13.

[0022]

The memory 12 includes, for example, a semiconductor storage medium such as a random-access memory (RAM), a read-only memory (ROM), or a solid-state drive (SSD). The memory 12 may store personal parallax of each worker W, vertical parallax of the worker W for each of a plurality of heights from the worker W, and a predetermined range from each of a plurality of targets T. The personal parallax is the difference in the position of the fingertip F among the workers W pointing and calling. The vertical parallax indicates the trend of the position of the fingertip F of the worker W pointing at and calling targets T having different heights. The predetermined range is a range within which the worker W is allowed to approach the target T.

[0023]

The processor 13 is formed, for example, by a central processing unit (CPU), a graphics processing unit (GPU), a field-programmable gate array (FPGA), or an application-specific integrated circuit (ASIC). The processor 13 includes a calculation section 21, a creation section 22, a setting section 23, an estimation

section 24, and an identification section 25.

[0024]

The calculation section 21 calculates the positional relation between the camera 11 and the eyes of the worker W by performing a later-described calibration. The calibration is performed in advance before maintenance and inspection is started by the worker W. The calculation section 21 may calculate the distance between the fingertip F and the target T on the basis of an environmental map, described later, of a space imaged by the camera 11. Further, the calculation section 21 may calculate the distance between the eyes and fingertip F of the worker W on the basis of the positional relation between the camera 11 and the eyes of the worker W.

[0025]

The creation section 22 creates the environmental map of the space imaged by the camera 11 by performing, for example, simultaneous localization and mapping (SLAM), on the basis of a spatial image captured by the camera 11.

[0026]

The setting section 23 sets a line-of-sight plane P (FIG. 5B) on the basis of the positional relation calculated by the calculation section 21. The line-of-sight plane P contains the target T and the eyes and fingertip F of the worker W in the environmental map. As

an alternative, the setting section 23 may set the line-of-sight plane P on the basis of the positional relation and the personal parallax. As another alternative, the setting section 23 may set the line-of-sight plane P on the basis of the positional relation and the vertical parallax. As yet another alternative, the setting section 23 may set the line-of-sight plane P on the basis of the positional relation, the personal parallax, and the vertical parallax.

[0027]

The estimation section 24 estimates the line of sight L1 of the worker W in the line-of-sight plane P on the basis of the coordinate difference between a central coordinate image and fingertip F in the captured image i1 (FIG. 5C).

[0028]

The identification section 25 identifies the target T pointed at by the worker W on the basis of the line of sight L1 of the worker W. In this instance, the eyes and fingertip F of the worker W and the target T are arranged on the line of sight L1 of the worker W in the order named.

[0029]

FIG. 6 is a schematic diagram illustrating an approach distance according to the first embodiment.

[0030]

The warning section 14 generates an alert A1 when the distance between the target T and the fingertip F of the worker W approaches the predetermined range. Further, the warning section 14 generates the alert A1 when the distance between the eyes and fingertip F of the worker W is shorter than a first distance (e.g., 15 cm) or equal to or longer than a second distance (e.g., more than 1.5 times longer than the average arm length of an adult), which is longer than the first distance. Furthermore, the warning section 14 generates the alert A1 when the position of the fingertip F in the environmental map is away from a previous position of the fingertip F by at least a third distance.

[0031]

FIG. 7 is a diagram illustrating the screen of a display device according to the first embodiment.

[0032]

The display section 15 may be formed, for example, by a display or other display device. The display section 15 displays a processed image i2 within the captured image i1. The processed image i2 is obtained by accentuating the target T and the line of sight L1 of the worker W. When displaying the processed image i2, the display section 15 may alternatively accentuate either

one of the target T and the line of sight L1 of the worker W.

[0033]

The following describes the calibration that is performed to calculate the parallax θ between the line of sight L1 of the worker W and the orientation L2 of the camera 11.

[0034]

FIG. 8 is a schematic diagram illustrating the calibration according to the first embodiment. FIG. 9 is a diagram illustrating the parallax that is calculated from the calibration according to the first embodiment.

[0035]

As depicted in FIG. 8, the camera 11 is attached to the body (e.g., forehead) of the worker W. A marker M (e.g., AR marker) is disposed at a predetermined distance from the worker W as an example of a "reference target." The marker M is positioned vertically at a predetermined height. This enables the worker W to perform the calibration with ease. The worker W stands upright at the predetermined distance from the marker M, confronts the marker M, and aligns the line of sight L1 with the marker M.

[0036]

The camera 11 captures an image of the marker M.

The calculation section 21 recognizes the marker M in the captured image i1 captured by the camera 11, and calculates two-dimensional coordinates p_M of the marker M in the captured image i1, a rotation vector R indicating the positional relation between the marker M and the camera 11, and a translation vector $t = (t_x, t_y, t_z)$. When the marker M in the line-of-sight plane P (line of sight L1) is at a distance of t (m) from the camera 11 in the above instance, the marker M is imaged at the coordinates p_M in the coordinate system of the camera 11 (captured image i1).

[0037]

The calculation section 21 calculates the parallax θ between the line of sight L1 and the orientation L2 of the camera 11 on the basis of the rotation vector R. The calculation section 21 is able to convert from an image coordinate system to the line-of-sight plane P on the basis of the coordinates p_M and the parallax θ , and is thus able to convert fingertip coordinates in the captured image i1 to three-dimensional coordinates. Since the eyes of the worker W are positioned vertically below the camera 11, the coordinates of the eyes are $(0, 0, t_z)$.

[0038]

FIG. 10 is a flowchart illustrating the target

identification process according to the first embodiment.

[0039]

First of all, before maintenance and inspection is started by the worker W, the calculation section 21 performs the calibration to calculate the positional relation between the eyes of the worker W and the camera 11 (step S1).

[0040]

Next, the creation section 22 creates the environmental map of the space imaged by the camera 11 by performing, for example, SLAM on the basis of the spatial image captured by the camera 11 (step S2). Next, the setting section 23 sets the line-of-sight plane P on the basis of the positional relation calculated by the calculation section 21 (step S3). The line-of-sight plane P contains the target T and the eyes and fingertip F of the worker W in the environmental map.

[0041]

Next, the estimation section 24 estimates the line of sight L1 of the worker W in the line-of-sight plane P on the basis of the coordinate difference between the central coordinates and fingertip F in the captured image i1 (step S4). Next, the identification section 25 identifies the target T pointed at by the worker W on the basis of the line of sight L1 of the worker W (step S5).

[0042]

According to the above-described configuration, the target identification system 10, which identifies the target T pointed at by the worker W on the basis of the image captured by the camera 11 attached to the worker W, includes the calculation section 21, the creation section 22, the setting section 23, the estimation section 24, and the identification section 25. The calculation section 21 calculates the positional relation between the camera 11 and the eyes of the worker W on the basis of the marker M, which is imaged by the camera 11 while the worker W confronts the marker M disposed at the predetermined distance. The creation section 22 creates the environmental map of the space imaged by the camera 11 on the basis of the spatial image captured by the camera 11. The setting section 23 sets the line-of-sight plane P on the basis of the positional relation. The line-of-sight plane P contains the target T and the eyes and fingertip F of the worker W in the environmental map. The estimation section 24 estimates the line of sight L1 of the worker W in the line-of-sight plane P on the basis of the coordinate difference between the central coordinates and fingertip F in the captured image i1, which is obtained when the fingertip F and the target T are imaged by the camera 11 while the target T is pointed

at by the worker W. The identification section 25 identifies the target T pointed at by the worker W on the basis of the line of sight L1. Consequently, the target T pointed at by the worker W can be properly identified on the basis of the image captured by the camera 11 attached to the worker W.

[0043]

Further, the target identification system 10 includes the memory 12, which records the personal parallax of each of a plurality of workers W. The setting section 23 sets the line-of-sight plane P on the basis of the personal parallax and the positional relation between the camera 11 and the eyes of the worker W. Consequently, the line-of-sight plane P can be properly set even when there is a difference between individual workers W.

[0044]

Furthermore, the target identification system 10 includes the memory 12, which records the vertical parallax of the worker W for each of a plurality of heights from the worker W. The setting section 23 sets the line-of-sight plane P on the basis of the vertical parallax and the positional relation between the camera 11 and the eyes of the worker W. Consequently, the line-of-sight plane P can be properly set even at a work site

where the worker W looks up at the target T or looks down at the target T.

[0045]

Moreover, the target identification system 10 includes the memory 12, which records the predetermined range from each of a plurality of targets T, and the warning section 14, which generates the alert Al. The calculation section 21 calculates the distance between the fingertip F and the target T on the basis of the environmental map. The warning section 14 generates the alert Al when the distance between the fingertip F and the target T approaches the predetermined range. Consequently, it is possible to inhibit the worker W from unduly approaching an electrified target T.

[0046]

Additionally, the target identification system 10 includes the warning section 14, which generates the alert Al. The calculation section 21 calculates the distance between the eyes and fingertip F of the worker W on the basis of the positional relation between the camera 11 and the eyes of the worker W. The warning section 14 generates the alert Al when the distance between the eyes and fingertip F of the worker W is shorter than the first distance or equal to or longer than the second distance, which is longer than the first

distance, or when the position of the fingertip F in the environmental map is away from a previous position of the fingertip F by at least the third distance. Consequently, the worker W is able to confirm a change in the position or orientation of the camera 11 that is caused by a collision between the camera 11 and another object or by a loosened brace of the camera 11.

[Second Embodiment]

[0047]

A target identification system 30 according to a second embodiment of the present invention will now be described. The only difference between the target identification system 30 and the target identification system 10 according to the first embodiment lies in the configuration of the processor. The processor included in the target identification system 30 is designated by the reference numeral 33. The other parts of configuration of the target identification system 30 are similar to those of the target identification system 10 according to the first embodiment. Therefore, the following mainly describes the difference from the first embodiment.

[0048]

FIG. 11 is a diagram illustrating the target identification system 30 for a work site according to the

second embodiment. FIG. 12 is a flowchart illustrating the target identification process according to the second embodiment.

[0049]

The processor 33 in the target identification system 30 includes the calculation section 21, the creation section 22, an estimation section 44, and an identification section 45.

[0050]

In the first embodiment, it is assumed that the fingertip F of the worker W is positioned near the vertical center of the viewing angle V of the worker W. Meanwhile, in the second embodiment, it is assumed that the fingertip F is positioned near the horizontal and vertical center of the viewing angle V of the worker W. Therefore, the line of sight L1 can be estimated without setting the line-of-sight plane P. Consequently, the estimation section 44 estimates the line of sight L1 from the above assumption and the positional relation between the camera 11 and the eyes of the worker W. The identification section 45, on the basis of the line of sight L1, identifies the target T that is gazed at by the worker W near the horizontal and vertical center of the viewing angle V. Further, in the case of the above assumption, the information about the fingertip F is not

required for estimating the line of sight L1. Therefore, in the second embodiment, pointing and calling need not be conducted.

[0051]

According to the above-described configuration, the target T gazed at by the worker W can be easily and properly identified on the basis of the image captured by the camera 11 attached to the worker W.

[Third Embodiment]

[0052]

A target identification system 50 according to a third embodiment of the present invention will now be described. The only difference between the target identification system 50 and the target identification system 10 according to the first embodiment lies in the position of the camera 11 attached to the worker W. The other parts of configuration of the target identification system 50 are similar to those of the target identification system 10 according to the first embodiment. Therefore, the following mainly describes the difference from the first embodiment.

[0053]

FIG. 13 is a diagram illustrating the target identification system 50 for a work site according to the third embodiment.

[0054]

The camera 11 included in the target identification system 50 is attached to the right side of the helmet H worn on the head of the worker W. More specifically, the camera 11 included in the target identification system 50 is positioned to the right of the eyes of the worker W.

[0055]

According to the above-described configuration, the target T pointed at by the worker W can be properly identified on the basis of the image captured by the camera 11 attached to the worker W in a situation where the fingertip F of the worker W pointing at and calling the target T is positioned somewhere near the horizontal center of the viewing angle V of the worker W.

[0056]

It should be noted that the present invention is not limited to the foregoing embodiment and extends to various modifications. For example, the foregoing embodiments have been described in detail in order to facilitate the understanding of the present invention, and are not necessarily limited to a configuration including all the described components. Further, some components of an embodiment may be replaced by the components of another embodiment. Furthermore, the

components of an embodiment may be added to the components of another embodiment. Moreover, some components of other embodiments may be subjected to the addition of other components, deleted, or replaced by other components.

WHAT IS CLAIMED IS:

1. A target identification system for identifying a target pointed at by a worker, on a basis of an image captured by an imaging unit of a monocular type, the imaging unit being attached to the worker, the target identification system comprising:

a calculation section that calculates a positional relation between eyes of the worker and the imaging unit on a basis of a reference image that is captured by the imaging unit while the worker confronts a reference target placed at a predetermined distance;

a creation section that creates an environmental map of a space imaged by the imaging unit, on a basis of a spatial image captured by the imaging unit;

a setting section that sets a line-of-sight plane on a basis of the positional relation, the line-of-sight plane containing the target and the eyes and fingertip of the worker in the environmental map;

an estimation section that estimates a line of sight of the worker in the line-of-sight plane on a basis of coordinate difference between central coordinates and the fingertip in a predetermined image that is captured by the imaging unit to depict the fingertip and the target while the target is pointed at by the worker; and

an identification section that identifies the target pointed at by the worker, on a basis of the line of sight.

2. A target identification system for identifying a target gazed at by a worker, on a basis of an image captured by an imaging unit of a monocular type, the imaging unit being attached to the worker, the target identification system comprising:

a calculation section that calculates a positional relation between eyes of the worker and the imaging unit on a basis of a reference image that is captured by the imaging unit while the worker confronts a reference target placed at a predetermined distance;

a creation section that creates an environmental map of a space imaged by the imaging unit, on a basis of a spatial image captured by the imaging unit;

an estimation section that estimates a line of sight of the worker in the environmental map on a basis of the positional relation; and

an identification section that identifies the target gazed at by the worker, on a basis of the line of sight.

3. The target identification system according to claim 1 or 2, wherein the reference target includes a marker that is positioned vertically at a predetermined

height.

4. The target identification system according to claim 1, further comprising:

a storage section that records personal parallax of each of a plurality of the workers, wherein

the setting section sets the line-of-sight plane on a basis of the positional relation and the personal parallax.

5. The target identification system according to claim 1, further comprising:

a storage section that records vertical parallax of the worker for each of a plurality of heights from the worker W, wherein

the setting section sets the line-of-sight plane on a basis of the positional relation and the vertical parallax.

6. The target identification system according to claim 1 or 2, further comprising:

a storage section that records a predetermined range from each of a plurality of the targets; and

a warning section that generates an alert,
wherein

the calculation section calculates a distance between the fingertip and the target on a basis of the environmental map, and

the warning section generates the alert when the distance between the fingertip and the target approaches the predetermined range.

7. The target identification system according to claim 1, further comprising:

a warning section that generates an alert,
wherein

the calculation section calculates a distance between the eyes and fingertip of the worker on the basis of the positional relation between the eyes of the worker and the imaging unit, and

the warning section generates the alert when the distance between the eyes and fingertip of the worker is shorter than a first distance or equal to or longer than a second distance or when a position of the fingertip in the environmental map is away from a previous position of the fingertip by at least a third distance, the second distance being longer than the first distance.

8. The target identification system according to claim 1 or 2, further comprising:

a display section that displays a processed image within the predetermined image, the processed image being obtained by accentuating at least either one of the target and the line of sight of the worker.

9. A target identification method used by a

target identification system for identifying a target pointed at by a worker, on a basis of an image captured by an imaging unit of a monocular type, the imaging unit being attached to the worker, the target identification method comprising:

calculating a positional relation between eyes of the worker and the imaging unit on a basis of coordinate difference between central coordinates and the target in a reference image that is captured by the imaging unit while the worker confronts a reference target placed at a predetermined distance;

creating an environmental map of a space imaged by the imaging unit, on a basis of a spatial image captured by the imaging unit;

setting a line-of-sight plane on a basis of the positional relation, the line-of-sight plane containing the target and the eyes and fingertip of the worker in the environmental map;

estimating a line of sight of the worker in the line-of-sight plane on a basis of the coordinate difference between the central coordinates and the fingertip in a predetermined image that is captured by the imaging unit to depict the fingertip and the target while the target is pointed at by the worker; and

identifying the target pointed at by the worker,

on a basis of the line of sight.

10. A target identification method used by a target identification system for identifying a target gazed at by a worker, on a basis of an image captured by an imaging unit of a monocular type, the imaging unit being attached to the worker, the target identification method comprising:

calculating a positional relation between eyes of the worker and the imaging unit on a basis of coordinate difference between central coordinates and the target in a reference image that is captured by the imaging unit while the worker confronts a reference target placed at a predetermined distance;

creating an environmental map of a space imaged by the imaging unit, on a basis of a spatial image captured by the imaging unit;

estimating a line of sight of the worker in the environmental map on a basis of the positional relation; and

identifying the target gazed at by the worker, on a basis of the line of sight.