

ELEVATOR PASSENGER DETECTION SYSTEM

FIELD

Embodiments described herein relate generally to an elevator passenger detection system.

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BACKGROUND

When a car door of an elevator opens, a finger or other parts of a passenger in the car may be pulled into a door pocket. In addition, when a passenger in a hall gets into the car, a passenger may hit an edge of a closing door. A system which aims to prevent such door accidents by detecting passengers in a hall and a car with a camera installed in the car and reflecting the detection on the door open and close control, is known.

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In the above-mentioned system, the presence or absence of passengers is detected by a luminance difference between frames of captured images. For example, however, when shadows of passengers enter the captured images due to the lighting environment in the car and the hall, over-detection may occur in accordance with the luminance variation caused by the shadow's motion. The term "over-detection" means mistakenly detecting a shadow as a passenger, which is a synonym for "false detection".

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Embodiments described herein aim to provide an elevator passenger detection system capable of correctly detecting passengers in a car and a hall by suppressing over-detection of a shadow caused by the lighting environment.

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SUMMARY

According to one embodiment, an elevator passenger detection system includes a luminance gradient detection unit detecting a luminance gradient direction

in each pixel of a captured image of a camera, in any angle unit, a differential feature amount generation unit generating a differential feature amount for extracting variation in the luminance gradient
5 direction detected by the luminance gradient detection unit, a moving body detection unit detecting a portion where the luminance gradient direction is changed from the captured image as a moving body, based on the differential feature amount generated by the
10 differential feature amount generation unit, and a person detection unit detecting the moving body as a person, based on information on the moving body detected by the moving body detection unit.

BRIEF DESCRIPTION OF THE DRAWINGS

15 FIG. 1 is a view showing a configuration of an elevator passenger detection system according to one of the embodiments.

FIG. 2 is a view showing a configuration of an area around a doorway in a car according to the
20 embodiment.

FIG. 3 is a view illustrating a coordinate system in a real space according to the embodiment.

FIG. 4 is a view showing an example of an image captured by a camera according to the embodiment.

25 FIG. 5 is a view schematically showing a configuration of a ride detection area according to the embodiment.

FIG. 6 is a view illustrating false detection of a shadow generated in a pull-in detection area according
30 to the embodiment.

FIG. 7 is a view showing an example of an edge filter (horizontal component) according to the embodiment.

FIG. 8 is a view showing an example of an edge filter (vertical component) according to the embodiment.

5 FIG. 9 is a graph showing an example of an edge vector according to the embodiment.

FIG. 10 is a view showing an example of an original image according to the embodiment.

10 FIG. 11 is a view showing an example of a luminance gradient direction image according to the embodiment.

FIG. 12 is a view showing a correspondence between a luminance gradient direction and a luminance value according to the embodiment.

15 FIG. 13 is a view showing an example of a motion image according to the embodiment.

FIG. 14 is a flowchart showing a processing operation of a passenger detection system.

FIG. 15 is a flowchart showing a detection process executed in step S103 of FIG. 14.

20 DETAILED DESCRIPTION

Embodiments will be described hereinafter with reference to the accompanying drawings.

25 The disclosure is merely an example and is not limited by contents described in the embodiments described below. Modifications that a person skilled in the art could easily conceive shall be included in the scope of the disclosure. In order to make the invention more clear, sizes and shapes of portions in the drawings may be modified in relation to the actual
30 embodiments. Constituent elements corresponding to each other in a plurality of drawings are denoted by like reference numerals and their detailed descriptions may be omitted unless necessary.

FIG. 1 is a view showing a configuration of an elevator passenger detection system according to one of the embodiments. The system with one car will be described as an example, but a system with a plurality of cars is constituted similarly.

In an upper part of a doorway of a car 11, a camera 12 is installed. More specifically, the camera 12 is installed in a modesty panel 11a which covers the upper part of the doorway of the car 11, with a lens portion tilted just below or tilted at a predetermined angle toward a hall 15 side or an inside of the car 11.

The camera 12 is, for example, a compact monitoring camera such as an in-vehicle camera, equipped with a wide-angle lens or a fisheye lens, and can continuously capture images of several frames per second (for example, 30 frames/sec). The camera 12 is activated, for example, when the car 11 arrives at the hall 15 on each floor, and captures images of an area around a car door 13 and the hall 15. The camera 12 may be in operation at all times during the operation of the car 11.

At this time, the capture range is adjusted to be $L1 + L2$ ($L1 > L2$). $L1$ refers to a capture range on the hall side, with a predetermined distance from the car door 13 to the hall 15. $L2$ refers to a capture range on the car side, with a predetermined distance from the car door 13 to a back surface of the car. It is assumed that $L1$ and $L2$ are ranges in the depth direction and that a range in a width direction (i.e., a direction orthogonal to the depth direction) is greater than at least a width of the car 11.

In the hall 15 of each floor, a hall door 14 is installed at an entrance of the car 11 so as to freely

open and close. The hall door 14 opens and closes in engagement with the car door 13 when the car 11 arrives. A power source (a door motor) is located on the car 11 side, and the hall door 14 only opens/closes following the car door 13. In the following descriptions, it is assumed that the hall door 14 is opened when the car door 13 is opened and that the hall door 14 is closed when the car door 13 is closed.

Each of images (video) sequentially captured by the camera 12 is subjected to analytical processing by an image processor 20 in real time. The image processor 20 is extracted from the car 11 for convenience in FIG. 1 but, in reality, the image processor 20 is accommodated in the modesty panel 11a together with the camera 12.

The image processor 20 comprises a storage unit 21 and a detection unit 22. The storage unit 21 is composed of, for example, a memory device such as RAM. The storage unit 21 includes a buffer area to sequentially store the images captured by the camera 12 and to temporally store data necessary for the processing of the detection unit 22. Images subjected to processing such as a distortion correction, scaling, and a partial cutting may be stored in the storage 21, as preprocessing for captured images.

The detection unit 22 is composed of, for example, a microprocessor and detects passengers in the car 11 or the hall 15 with the images captured by the camera 12. The detection section 22 is functionally composed of a detection area setting unit 23 and a detection processing unit 24. These may be realized by software, hardware such as integrated circuits (IC), or a combination of software and hardware. In addition, an

elevator controller 30 may comprise some or all functions of the image processor 20.

5 The detection area setting unit 23 sets at least one or more detection areas for detecting passengers on the captured images obtained from the camera 12. In the present embodiment, a detection area E1 for detecting passengers in the hall 15 and detection areas E2 and E3 for detecting passengers in the car 11 are set. The detection area E1 is used as the ride
10 detection area, and is set from the doorway (car door 13) of the car 11 to the hall 15. The detection area E2 is used as a pull-in detection area and is set at entrance panels 41a and 41b in the car 11. The detection area E3 is used as a pull-in detection area,
15 similarly to the detection area E2, and is set on a floor surface 19 on the doorway side in the car 11 (see FIG. 3).

The detection processing unit 24 includes a luminance gradient detection unit 24a, a differential
20 feature amount generation unit 24b, a moving body detection unit 24c, and a person detection unit 24d, and analyzes the captured images obtained from the camera 12 to detect passengers present in the car 11 or the hall 15. The luminance gradient detection unit
25 24a, the differential feature amount generation unit 24b, the moving body detection unit 24c, and the person detection unit 24d will be described later in detail with reference to FIG. 7 to FIG. 13. When a passenger detected by the detection processing unit 24 is present
30 in any of the above-mentioned detection areas E1 to E3, a predetermined response process (door open and close control) is executed.

The elevator controller 30 is composed of a

computer equipped with CPU, ROM, RAM, and the like.
The elevator controller 30 executes control of the
operation of the car 11, and the like. In addition,
the elevator controller 30 comprises a door open and
close control unit 31 and an alarm unit 32.

The door open and close control unit 31 controls
opening and closing of the car door 13 when the car 11
arrives at the hall 15. More specifically, the door
open and close control unit 31 opens the car door 13
when the car 11 arrives at the hall 15, and closes the
car door after a predetermined time has elapsed.
However, if a passenger is detected in the detection
area E1 by the detection processing unit 22b during the
closing operation of the car door 13, the door open and
close control unit 31 prohibits the closing operation
of the car door 13, and re-opens the car door 13 in the
fully open direction to maintain the door open state.

In addition, if a passenger is detected in the
detection area E2 or E3 by the detection processing
unit 22b during the opening operation of the car door
13, the door open and close control unit 31 executes
the door open and close control to avoid a door
accident (i.e., an accident of pulling into the door
pocket). More specifically, the door open and close
control unit 31 temporarily suspends the opening
operation of the car door 13, moves the car door 13 in
an opposite direction (i.e., the door closing
direction), or reduces the opening speed of the car
door 13.

FIG. 2 is a view showing the configuration of an
area around the doorway in the car 11.

The car door 13 is provided at the doorway of the
car 11 to freely open and close. In the example shown

in FIG. 2, a double car door 13 is shown and two door panels 13a and 13b, which constitute the car door 13, open and close in opposite directions along a frontage direction (horizontal direction). The "frontage" is a synonym for the doorway of the car 11.

Entrance panels 41a and 41b are provided on both sides of the doorway of the car 11 to surround the doorway of the car 11 together with the modesty panel 11a. The "entrance panel" is also referred to as a front return panel and is generally equipped with a door pocket for accommodating the car door 13 on the back side. In the example shown in FIG. 2, when the car door 13 opens, one of the door panels 13a is accommodated in a door pocket 42a provided on a back side of the entrance panel 41a, and the other door panel 13b is accommodated in a door pocket 42b provided on a back side of the entrance panel 41b. An indicator 43, an operating panel 45 on which the destination floor buttons 44 and the like are arranged, and a speaker 46 are installed on one or both of the entrance panels 41a and 41b. In the example shown in FIG. 2, the speaker 46 is installed on the entrance panel 41a, and the indicator 43 and the operating panel 45 are installed on the entrance panel 41b.

The camera 12 is provided in the modesty panel 11a horizontally arranged at the upper part of the doorway of the car 11. The camera 12 is provided in accordance with the closing position of the car door 13 to detect passengers in the hall 15 until the door closes. More specifically, if the car door 13 is a double door type, the camera 12 is provided in the center of the modesty panel 11a. In addition, for example, a lighting device 48 using LEDs is installed on the ceiling inside the

car 11.

As shown in FIG. 3, the camera 12 capture images in which a direction horizontal to the car door 13 provided at the doorway of the car 11 is referred to as an X-axis, a direction from the center of the car door 13 to the hall 15 (i.e., the direction perpendicular to the car door 13) is referred to as a Y-axis, and a direction of the height of the car 11 is referred to as a Z-axis.

FIG. 4 is a view showing an example of an image captured by the camera 12. The upper side shows the hall 15, and the lower side shows the inside of the car 11. In the figure, 16 denotes a floor surface of the hall 15, and 19 denotes a floor surface of the car 11. E1, E2, and E3 refer to detection areas.

The car door 13 includes two door panels 13a and 13b that move in opposite directions on a car sill 47. Similarly, the hall door 14 includes two door panels 14a and 14b that move in opposite directions on a hall sill 18. The door panels 14a and 14b of the hall door 14 move in the door opening and closing directions together with the door panels 13a and 13b of the car door 13.

The camera 12 is installed at the upper part of the doorway of the car 11. Therefore, when the door of the car 11 opens in the hall 15, a predetermined range (L1) on the hall side and a predetermined range (L2) inside the car are captured as shown in FIG. 1. The detection area E1 is set in the predetermined range (L1) on the hall side, of the ranges, to detect a passenger riding the car 11.

In real space, the detection area E1 has a distance L3 from the center of the doorway (frontage)

toward the hall direction ($L3 \leq$ capture range $L1$ on the hall side). A breadth $W1$ of the detection area $E1$ in a fully open state is set to a distance longer than or equal to a breadth $W0$ of the doorway (frontage). The detection area $E1$ includes the sills 18 and 47 and is set except for blind spots of jambs 17a and 17b, as represented by hatch lines in FIG. 4. The size of the detection area $E1$ in the horizontal direction (X-axis direction) may be changed in accordance with the opening and closing operations of the car door 13. In addition, the size of the detection area $E1$ in the vertical direction (Y-axis direction) may also be changed in accordance with the opening and closing operations of the car door 13.

As shown in FIG. 5, the detection area $E1$ used as the ride detection area is composed of a ride intention estimation area $E1a$, a proximity detection area $E1b$, and a sill top detection area $E1c$. The ride intention estimation area $E1a$ is an area for estimating whether or not a passenger is moving toward the car 11 with a ride intention. The proximity detection area $E1b$ is an area for detecting the proximity of a passenger to the doorway of the car 11. The sill top detection area $E1c$ is an area for detecting a passenger passing over the sills 18 and 47.

This system includes detection areas $E2$ and $E3$ in addition to the detection area $E1$ for ride detection. The detection areas $E2$ and $E3$ are used as pull-in detection areas. The detection area $E2$ is set with a predetermined width, along inner side surfaces 41a-1 and 41b-1 of the entrance panels 41a and 41b of the car 11. The detection area $E2$ may be set in accordance with the breadth of the inner side surfaces 41a-1 and

41b-1. The detection area E3 is set with a predetermined width along the car sill 47 of the floor surface 19 of the car 11.

When a passenger is detected in the detection area E2 or E3 during the opening operation of the car door 13, for example, a response operation such as temporarily suspending the opening operation of the car door 13, moving the car door 13 in an opposite direction (door closing direction), or reducing the opening speed of the car door 13 is executed. In addition, for example, a warning "Please move away from the door" is given by a voice announcement.

(Problem on detection process)

In general, the pull-in detection is executed on the assumption that the luminance variation of the images in the detection areas E2 and E3, i.e., the pull-in detection areas, is correctly represented by passenger's intrusion. However, the detection areas E2 and E3 are strongly affected by the lighting environment in the car room since the areas are set inside the car 11. In other words, as shown in FIG. 6, even when a passenger P1 is located at a position remote from the car door 13, a shadow S1 of the passenger P1 may enter the detection area E2 or E3 due to the illumination of the lighting device 48. When the shadow S1 enters the detection area E2 or E3, a large variation in luminance may occur on the image in accordance with the motion of the shadow S1, and the shadow S1 may be over-detected as the passenger P1.

This also occurs in a ride detection process. In other words, the detection area E1, which is the ride detection area, is set in the hall 15 around the doorway of the car 11. If the shadow enters the

detection area E1 due to the lighting environment of the hall 15, the shadow may be over-detected due to a luminance variation on the image. Therefore, the present embodiment is configured such that the detection processing unit 24 of the image processor 20 shown in FIG. 1 comprises the following functions (generation of a luminance gradient direction image, generation of a differential feature amount, moving body detection, and person detection) to detect presence or absence of a passenger by focusing the variation in luminance gradient direction between images (between frames) continuously obtained as captured images.

(a) Generation of Luminance gradient direction image

The luminance gradient detection unit 24a detects the luminance gradient direction in each pixel of the image (original image) captured by the camera 12 in units of N degrees, and generates a luminance gradient direction image whose luminance gradient direction is visualized. The luminance gradient direction is calculated as a discrete value in units of N degrees. The N degrees are, for example, 45 degrees. When the luminance gradient direction is obtained in units of 45 degrees, nine values (eight values in units of 45 degrees + one value with no luminance gradient) including no luminance gradient can be obtained.

The degrees are not limited to nine values (N degrees = 45 degrees). In addition, whether or not the values include no luminance gradient is optional. At least four or more values of the luminance gradient direction are desirably obtained to correctly detect a person and a shadow separately. This is because, for

example, when a person wears black clothes, the person may not be distinguishable from its shadow in two-value luminance gradient orientations of the horizontal direction and the vertical direction. However, if the
5 luminance gradient direction is too fine, setting of a boundary between the detection and no detection becomes difficult. Therefore, obtaining the nine-value luminance gradient direction in units of 45 degrees is desirable in consideration of the detection accuracy
10 and the image processing.

* How to obtain luminance gradient direction

For example, the horizontal component and the vertical component of an edge vector of each pixel are obtained in units of 3×3 with sobel filters as shown in
15 FIG. 7 and FIG. 8, and a direction (angle) of the edge vector is calculated as shown in FIG. 9. The calculated direction of the edge vector is converted into the luminance gradient direction by, for example, rounding in units of 45 degrees. "Rounding" is to make
20 a numerical value fall within a range of predetermined digits by rounding off, rounding down, and the like. In other words, "rounding in units of 45 degrees" is to make a numerical value fall within ranges of 0 degrees, 45 degrees, 90 degrees, 135 degrees, 180 degrees,
25 225 degrees, 270 degrees, and 315 degrees. As a result, for example, when the direction of the edge vector is 40 degrees, 40 degrees are converted into 45 degrees.

A filter other than the sobel filter (for example,
30 Laplacian filter or the like) may be used as the edge filter. The unit of pixel for filtering is not limited to 3×3 either. In addition, a value with no luminance gradient may be included in the luminance gradient

direction. In this case, no luminance gradient is recognized if the luminance gradient intensity (i.e., magnitude of the edge vector) is smaller than or equal to a threshold value. The luminance gradient intensity may be calculated in a manner different from the luminance gradient direction. For example, the luminance gradient direction may be calculated with a sobel filter, and the luminance gradient intensity may be calculated with a Laplacian filter.

The specific examples are shown in FIG. 10 to FIG. 12.

FIG. 10 is a view showing an example of an original image. The upper side shows the hall, and the lower side shows the inside of the car. In the figure, P11 and P12 denote passengers, S11 denotes a shadow of the passenger P11, and S12 denotes a shadow of the passenger P12. FIG. 11 is a view showing an example of the luminance gradient direction image. The luminance gradient direction image is schematically shown but, in fact, expressed complicatedly with luminance values corresponding to the luminance gradient direction. FIG. 12 is a view showing a correspondence between the luminance gradient direction and the luminance values. Eight luminance gradient directions are expressed at every 45 degrees from 0 degrees, by arrows, in the angular directions of 360 degrees.

When the luminance gradient direction of each pixel of the original image in FIG. 10 is obtained in units of 45 degrees, nine values (eight values in units of 45 degrees + one value with no luminance gradient) including no luminance gradient can be obtained. The luminance gradient direction image as shown in FIG. 11 is generated by converting the nine values into any

luminance values as shown in FIG. 12.

In the example of FIG. 12, luminance values 0, 16, 32, 48, 64, 80, 96, and 112 are assigned in clockwise order to eight values in units of 45 degrees, and one value with no luminance gradient is set at luminance value 255. For example, the direction of 12 o'clock (i.e., direction of a top side in the figure) is converted into luminance value 96, and the direction of 6 o'clock (i.e., direction a bottom side in the figure) is converted into luminance value 32.

The manner of assigning the luminance values and the luminance values themselves are optional and are not limited to the example of FIG. 12. In short, the luminance gradient directions obtained in units of any angles are desirably replaced with any luminance values and visualized. This luminance gradient direction image does not need to be generated, but may be only processed on a computer.

(b) Generation of differential feature amount

The differential feature amount generation unit 24b generates the differential feature amount for extracting the variation (difference) in the luminance gradient direction. The "differential feature amount" refers to the feature amount based on the luminance gradient direction, including the luminance gradient direction in a pixel unit, the luminance gradient directions in plural pixel units (for example, block units), Histograms of Oriented Gradients (HOG), Co-Occurrence Histograms of Oriented Gradients (CoHOG), and the like.

In the luminance gradient directions in plural pixel units, a majority and an average of the luminance gradient directions of plural pixels of interest, the

direction of the largest luminance gradient intensity,
and the like are used. In HOG, a histogram in each
luminance gradient direction for plural pixels is used.
In CoHOG, a histogram in each combination
5 (cooccurrence) of luminance gradient directions for
plural pixels is used. For example, the number of
pixels in which facing rightward is adjacent to facing
upward is used.

(c) Moving body detection 1

10 The moving body detection unit 24c detects a part
where the luminance gradient direction is changed as a
moving body, by comparing the differential feature
amounts between the images continuously obtained as the
captured images. The "moving body" refers to an area
15 where an object making some motion is captured on the
captured image.

The unit for determining the variation or no
variation is the pixel unit or plural pixel units. An
index for determining the variation or no variation is
20 similarity of the differential feature amount as to
whether or not the differential feature amounts between
the images match, whether or not the distances in the
feature amount space are short, and the like. An
example of the method of determining the variation or
25 no variation is a determining method based on the
number of images where the luminance gradient
directions are changed. For example, when the
luminance gradient directions of focused images are
different in five sequential images, the variation is
30 determined. Alternatively, the variation or no
variation may be determined based on the rate of the
images where the luminance gradient directions are
changed. For example, "no variation" is determined

when the luminance gradient directions are different in the focused pixels of two of five images, and that the "variation" is determined when the luminance gradient directions are different in the focused pixels of three of five images. In other words, "no variation" is determined when the number of images different in luminance gradient direction is less than 50% of the predetermined number, and the "variation" is determined when the number of images is more than or equal to 50% of the predetermined number. The pixels of the part where the "variation" is determined (i.e., the part where the luminance gradient directions are changed) are extracted as the motion pixels.

FIG. 13 is a view showing an example of the motion image generated by the moving body detection unit 24c. In the figure, 50 denotes a motion pixel. In the image of the passenger P11, a number of motion pixels 50 are extracted since the luminance gradient directions are changed in a number of parts in accordance with the motion of the passenger P11 such as the colors and creases of clothes, gaps of fingers, and the like. In contrast, light and shade hardly vary, and only occur/disappear in an image of a shadow S11. Therefore, the luminance gradient directions are changed in a small number of parts, and a number of motion pixels 50 that can be determined as the moving body are not extracted. As described below, whether or not the moving body is a person can be determined from the distribution of the motion pixels 50.

It is assumed that a passenger P12 is already on board in the car 11 and is standing near the entrance. For this reason, a number of motion pixels 50 that can be determined as a moving body cannot be extracted from

an image of the passenger P12 and an image of a shadow S22.

(d) Moving body detection 2

5 The moving body detection may be executed using both the variation in luminance gradient direction (luminance gradient direction difference) and the variation in luminance value (luminance difference). In this case, the moving body detection unit 24c obtains the luminance difference between the images
10 continuously obtained as the captured images, and detects the moving body based on the luminance gradient direction difference and the luminance difference. Examples of the method of integrating the result of the luminance gradient direction difference and the result
15 of the luminance difference include the logical operation (such as AND/OR operation or the like) and parameter change described below, and the like.

AND operation: When the motion pixels on an image are detected by both the luminance gradient direction
20 difference and the luminance difference, it is determined that the moving body exists within a predetermined range including the motion pixels.

OR operation: The luminance difference is used for an area with a number of variations in the luminance
25 gradient directions (i.e., an area which may be a shadow with a low possibility), and the luminance gradient direction difference is used for an area with a few variations in the luminance gradient directions (i.e., an area which may be a shadow with a high
30 possibility). The "area with a number of variations in the luminance gradient directions" refers to an area where the number of motion pixels is more than or equal to a number determined as a determination criterion of

the moving body. The "area with a few variations in the luminance gradient directions" refers to an area where the number of motion pixels is smaller than the number determined as the determination criterion of the moving body.

In addition, the luminance difference is used for an area where the luminance gradient directions are not uniform (i.e., an area which may be a shadow with small possibility), and the luminance gradient direction difference is used for an area where the luminance gradient directions are uniform (i.e., an area which may be a shadow with great possibility). The "area where the luminance gradient directions are not uniform" refers to an area where the number of pixels in directions different in luminance gradient is more than or equal to a rate determined as the determination criterion of the moving body. The "area where the luminance gradient directions are uniform" refers to an area where the number of pixels in directions different in luminance gradient is smaller than the rate determined as the determination criterion of the moving body.

Parameter change: the parameter of the luminance difference is made easier to detect (i.e., the threshold value of the luminance difference is made lower than the standard value) for the area with a number of variations in luminance gradient directions (i.e., the area which may be a shadow with small possibility), and, the parameter of the luminance difference is made difficult to detect (i.e., the threshold value of the luminance difference is made higher than the standard value) for the area with a few variations in luminance gradient directions (i.e., the

area which may be a shadow with great possibility).

(e) Person Detection

The person detection unit 24d detects the above moving body as a person, based on the information on the moving body detected by the moving body detection unit 24c. The "person" specifically refers to a passenger who exists in the car 11 or the hall 15. The "information on the moving body" includes at least one of the distribution of the motion pixels, the size of the moving body, and the moving body detection count.

The "distribution of the motion pixels" indicates a state of distribution of the motion pixels within a predetermined range. For example, if forty (i.e., approximately 10%) or more motion pixels exist in the range of 20×20 pixels, the motion pixels are determined as the motion of a person. The "size of the moving body" indicates the size of an aggregate of continuous motion pixels. For example, if forty or more motion pixels exist as a continuous aggregate, the motion pixels are determined as the motion of a person. The "moving body detection count" indicates the number of times at which the motion pixels are detected as the moving body in each image. For example, if the motion pixels are detected as the moving body a certain number of times at the same position in the image, the motion pixels are determined as the motion of a person.

This system detects a person (passenger) in the captured image, using the detection processing unit 24 having the above configuration and, if the person exists in one of the detection areas E1 to E3 shown in FIG. 3, executes the predetermined corresponding process (door open and close control). The processing operation of this system will be described below using

an example of the pull-in detection.

FIG. 14 is a flowchart showing the processing operation of this system. The processing shown in this flowchart is executed by the image processor 20 and elevator controller 30 shown in FIG. 1.

First, a detection area setting process is executed by the detection area setting unit 23 of the detection unit 22 provided in the image processor 20 as an initial setting (step S100). This detection area setting process is executed in a manner described below when, for example, the camera 12 is installed or the installation position of the camera 12 is adjusted.

In other words, the detection area setting unit 22a sets the detection area E1 having the distance L3 from the doorway to the hall 15, in a state in which the car door 13 is fully opened. As shown in FIG. 4, the detection area E1 includes the sills 18 and 47 and is set except for the blind spots of the jambs 17a and 17b. In the state in which the car door 13 is fully opened, the size of the detection area E1 in the horizontal direction (X-axis direction) is denoted by W1 and has a distance longer than or equal to the horizontal width W0 of the doorway (frontage). In addition, the detection area setting unit 22a sets the detection area E2 having a predetermined width along the inner side surfaces 41a-1 and 41b-1 of the entrance panels 41a and 41b of the car 11, and sets the detection area E3 having a predetermined width along the sill 47 of the floor surface 19 of the car 11.

During the normal operation, when the car 11 arrives at the hall 15 on any floor (Yes in step S101), the elevator controller 30 starts the opening operation of the car door 13 (step S102). In accordance with

this door opening operation, the predetermined range (L1) on the hall side and the predetermined range (L2) inside the car are captured at a predetermined frame rate (for example, 30 frames/sec) by the camera 12.

5 Capturing using the camera 12 may be continuously executed in a state in which the door of the car 11 is closed.

The image processor 20 obtains the images captured by the camera 12 on a time-series basis, and executes
10 the following detection process (i.e., a pull-in detection process) in real time while sequentially storing these images in the storage unit 21 (step S103). Distortion correction, enlargement and reduction, cutting a part of the image, and the like
15 may be executed as pretreatment for the captured images.

FIG. 15 shows the detection process executed in step S103. This detection process is executed by the detection processing unit 24 of the image processor 20.
20 Detecting the luminance gradient direction in the captured images is assumed below.

First, the detection processing unit 24 obtains each image (original image) from the memory unit 21 on a time-series basis (step S201) and generates a
25 luminance gradient direction image in which the luminance gradient direction in each image is visualized for each of these images (step S202). More specifically, the detection processing unit 24 calculates the direction (angle) of the edge vector of
30 each pixel in units of 3×3 , using, for example, a sobel filter, and converts the direction of the edge vector into the luminance gradient direction by, for example, rounding in units of 45 degrees. In addition, the

detection processing unit 24 obtains the luminance gradient intensity (i.e., magnitude of the edge vector) and recognizes no luminance gradient if this luminance gradient intensity is smaller than or equal to a
5 threshold value. The detection processing unit 24 converts nine values (i.e., eight values in units of 45 degrees + one value with no luminance gradient) including no luminance gradient into any luminance value to generate the luminance gradient direction
10 image.

Subsequently, the detection processing unit 24 executes differential binarization of the luminance gradient direction image (step S203). More specifically, the detection processing unit 24
15 binarizes the difference obtained by comparing the feature amounts in the luminance gradient direction between the images continuously obtained as the captured images, by a preset threshold value TH1. The threshold value TH1 is set to an optimum value
20 depending on the lighting environment inside the car 11 and in the hall 15, and the like.

In addition, the detection processing unit 24 also executes differential binarization of the original image, which is the captured image (step S204). More specifically, the detection processing unit 24 obtains
25 the luminance difference by comparing the luminance values of the respective pixels in the image at the same pixel position of the next image, and binarizes the luminance difference by a preset threshold value TH2. The threshold value TH2 is set to an optimum
30 value depending on the lighting environment in the car 11 and the hall 15, and the like, similarly to the threshold value TH1.

The detection processing unit 24 integrates the value obtained by binarizing the luminance gradient direction difference obtained from the luminance gradient direction images, with the value obtained by binarizing the luminance difference obtained from the original image (step S205), and detects the presence or absence of the moving body from the result of the integration process (step S206). Examples of the method of integrating the luminance gradient direction difference with the luminance difference include the logical operation (such as AND/OR operation and the like) and the parameter change as explained above, and the like.

Thus, when the moving body (motion pixel) is detected, the detection processing unit 24 detects a person, based on the information on the moving body (step S207). More specifically, the detection processing unit 24 determines whether or not the moving body is the motion of a person, based on at least one of the distribution of motion pixels, the size of the moving body, and the moving body detection count, which are obtained as the information on the moving body. For example, in a case of executing the person detection, based on the distribution of the motion pixels, if approximately 10% or more of the motion pixels exist within a predetermined pixel range, the detection processing unit 24 determines the range including the motion pixels as the motion of the person. In the present embodiment, the "person" refers to a passenger in the car 11 or the hall 15, and the motion of the passenger's clothes, hands, and the like are represented as the motion pixels in the captured image (see FIG. 13).

In the example in FIG. 13, the luminance gradient direction difference and the luminance difference have been used together, but the moving body detection process may be executed using the only luminance gradient direction difference, and a person (passenger) may be detected based on the distribution of the motion pixels and the like obtained as the detection result. In this case, the processes in steps S204 and S205 in FIG. 15 are unnecessary.

In FIG. 14, when a passenger is detected by the above detection process during the door opening operation, the detection processing unit 24 determines whether or not the passenger exists in the detection area E2 or E3, which is set as the pull-in detection area inside the car 11 (step S104). If the passenger exists in the detection area E2 or E3 (Yes in step S104), a pull-in detection signal is output from the detection processing unit 24 to the elevator controller 30. As a result, the elevator controller 30 temporarily suspends the opening operation of the car door 13 via the door open and close control unit 31 and restarts the door opening operation at its suspend position after several seconds, as a responsive process associated with the pull-in detection area (step S105).

As the responsive process, the opening speed of the car door 13 may be made slower than usual, or the door opening operation may be restarted after slightly moving the car door 13 in the opposite direction (door closing direction). In addition, voice announcement may be made through the speaker 46 in the car 11 to call attention urging a passenger to move away from the car door 13, or the alarm may be sounded, by activating the alarm unit 32 of the elevator controller 30 (step

S106). The above process is repeated while a passenger is detected in the detection area E2 or E3. As a result, for example, when a passenger exists near the car door 13, it is possible to prevent the passenger from being pulled into the door pocket 42a or 42b.

(Ride detection process)

In the example in FIG. 14, the pull-in detection process has been described as an example, but the ride detection process is also executed in the same manner.

In other words, when closing the door of the car 11 starts at any floor, the detection process described with reference to FIG. 15 is executed. As described above, when a passenger is detected based on the luminance gradient direction difference and the luminance difference of the captured image, it is determined whether or not the passenger exists in the detection area E1 which is recognized as a ride detection area in the hall 15. If it is detected that the passenger exists in the detection area E1 and is moving toward the door 13 of the car 11, a ride detection signal is output from the detection processing unit 24 to the elevator controller 30. As a result, the elevator controller 30 temporarily suspends the closing operation of the car door 13 via the door open and close control unit 31, moves the car door 13 in an opposite direction (i.e., the door closing direction), or makes the opening speed of the car door 13 slower than usual, as the responsive process associated with the ride detection area.

Thus, according to the present embodiment, it is possible to suppress over-detection of the shadow in the captured image, correctly detect the passenger, and realize the responsive process corresponding to the

detection result, by using the multi-value luminance gradient direction obtained in any angle units as the differential feature amount and executing the person detection based on the change in the luminance gradient direction.

The present applicant has conceived a method of detecting a person by extracting an edge in which a luminance value is varied in a mountain-shaped pattern as the differential feature amount, focusing a difference in luminance characteristic between a shadow and a person (Japanese Patent Application No. 2021-130127). Distinguishing a shadow from a person on the captured image and correctly detecting only the person are realized by this method. However, the differential feature amount is two values (presence or absence of the luminance gradient). In contrast, in this method, the differential feature amounts are nine values including no luminance gradient when the luminance gradient direction is obtained in, for example, units of 45 degrees. A boundary between the detection and no detection in the feature amount space can be finely set and the person can be detected at higher accuracy for the image close to the boundary, by expanding the differential feature amount from two values to nine values (expanding the feature amount space to ninth dimension).

In the above embodiment, detecting a passenger from the entire captured image has been assumed, but a passenger may be detected in each detection area that is set in advance on the captured image. For example, if the door is in the opening operation, the system focuses the images in the detection areas E2 and E3 shown in FIG. 4 and detects a passenger in the

detection area E2 or E3 by the luminance gradient direction difference in the images. Alternatively, if the door is in the closing operation, the system focuses the image in the detection area E1 shown in FIG. 4, and detects a passenger in the detection area E1 by the luminance gradient direction difference in the image.

According to at least one of the embodiments described above, the elevator passenger detection system capable of suppressing over-detection of shadows caused by the lighting environment and correctly detecting passengers in the car or the hall can be provided.

While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

WHAT IS CLAIMED IS:

1. A passenger detection system of an elevator comprising a camera installed in a car to capture a predetermined range including an inside of the car, the system comprising:

a luminance gradient detection unit detecting a luminance gradient direction in each pixel of a captured image of the camera, in any angle unit;

a differential feature amount generation unit generating a differential feature amount for extracting variation in the luminance gradient direction detected by the luminance gradient detection unit;

a moving body detection unit detecting a portion where the luminance gradient direction is changed from the captured image as a moving body, based on the differential feature amount generated by the differential feature amount generation unit; and

a person detection unit detecting the moving body as a person, based on information on the moving body detected by the moving body detection unit.

2. The system of claim 1, wherein the luminance gradient detection unit detects at least four or more values of the luminance gradient direction.

3. The system of claim 1, wherein the luminance gradient detection unit detects nine values of the luminance gradient direction including no luminance gradient.

4. The system of claim 1, wherein the moving body detection unit detects a part where the luminance gradient direction is changed as a moving body, by comparing the differential feature amounts between the images continuously obtained as the

captured images.

5. The system of claim 4, wherein
the moving body detection unit uses a rate at
which the differential feature amounts match or a rate
5 at which the differential feature amounts are similar,
in each of the images, as an index of variation
determination of the luminance gradient direction.

6. The system of claim 4, wherein
the moving body detection unit detects a part
10 where the luminance gradient direction is changed as a
moving body, based on the number or rate of images in
which the luminance gradient direction is determined to
be changed, of the images.

7. The system of claim 1, wherein
15 the moving body detection unit obtain a luminance
difference between images obtained continuously as the
captured images, and detects a moving body from the
captured images, based on the luminance gradient
direction difference and the luminance difference
20 between the images.

8. The system of claim 7, wherein
the moving body detection unit easily detects a
parameter of the luminance difference for an area with
a number of variations in the luminance gradient
25 direction, in the captured images, and hardly detects
the parameter of the luminance difference for an area
with a few variations in the luminance gradient
direction, in the captured images.

9. The system of claim 7, wherein
30 the moving body detection unit uses the luminance
difference for the area with a number of variations in
the luminance gradient direction, in the captured
images, and uses the luminance gradient direction

difference for the area with a few variations in the luminance gradient direction, in the captured images.

10. The system of claim 7, wherein

5 the moving body detection unit uses the luminance difference for an area where the luminance gradient direction is not uniform, in the captured images, and uses the luminance gradient direction difference for an area where the luminance gradient direction is uniform, in the captured images.

10 11. The system of claim 1, wherein

the person detection unit detects the moving body as a person, based on at least one of a distribution of motion pixels, a size of the moving body, and a moving body detection count, which are obtained as information
15 on the moving body.

12. The system of claim 1, further comprising:

a control unit which, when the person is detected in a detection area preset in the captured image, executes a responsive process associated with the
20 detection area.

13. The system of claim 12, wherein

the detection area is set near a door inside the car, and

the control unit controls door opening and closing
25 operations to prevent the person from being caught by a door during the door opening operation of the car, as the responsive process.