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(54) **GAS DETECTION DEVICE, GAS DETECTION METHOD, AND GAS DETECTION PROGRAM**

(71) Applicant: **KONICA MINOLTA, INC.**, Chiyoda-ku (JP)

(72) Inventors: **Akihiro SUZUKI**, Tokyo (JP); **Motohiro ASANO**, Osaka (JP); **Hiroshi TAKAHASHI**, Tokyo (JP)

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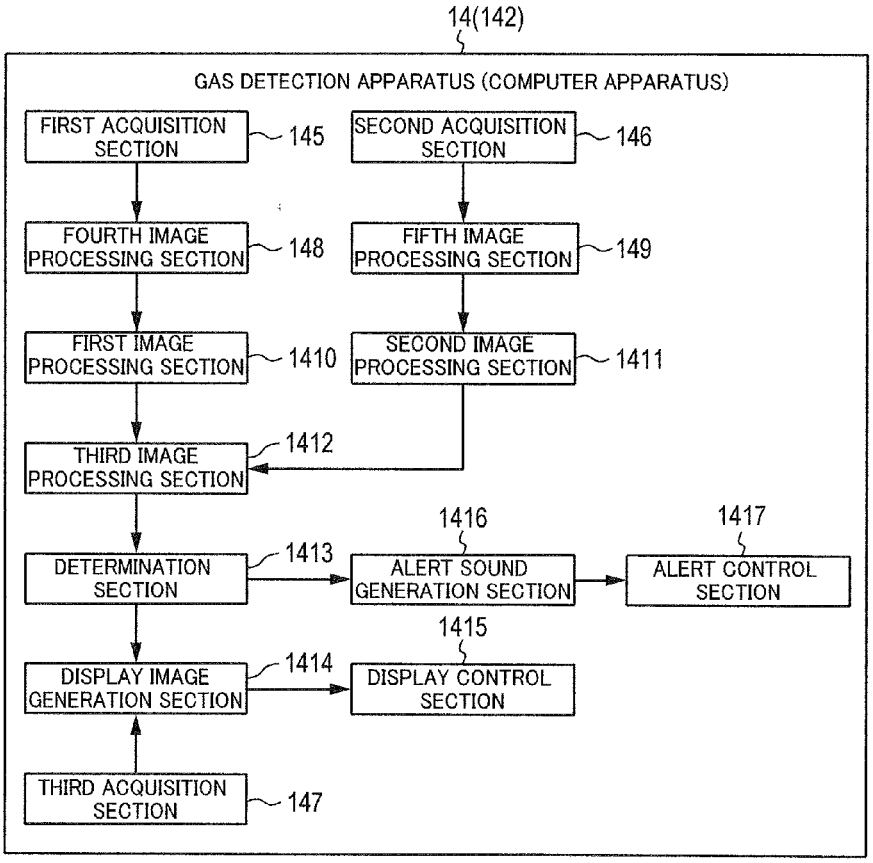
CPC ***G01N 21/3504*** (2013.01); ***G06T 5/50*** (2013.01); ***G01N 21/59*** (2013.01); ***G06T 1/0007*** (2013.01)

(57) **ABSTRACT**

The gas detection device according to the present invention is provided with: a first image processing unit for generating a first binary image for indicating in binary fashion the inside and outside of a first region indicating water vapor and a gas to be detected, on the basis of a first image generated using an optical filter having a first pass wavelength band including at least an absorption wavelength band of the gas; a second image processing unit for generating a second binary image indicating in binary fashion the inside and outside of a second region indicating the water vapor, on the basis of a second image generated using an optical filter having a second pass wavelength band different from the absorption wavelength band; and a third image processing unit for calculating a difference between the first binary image and the second binary image.



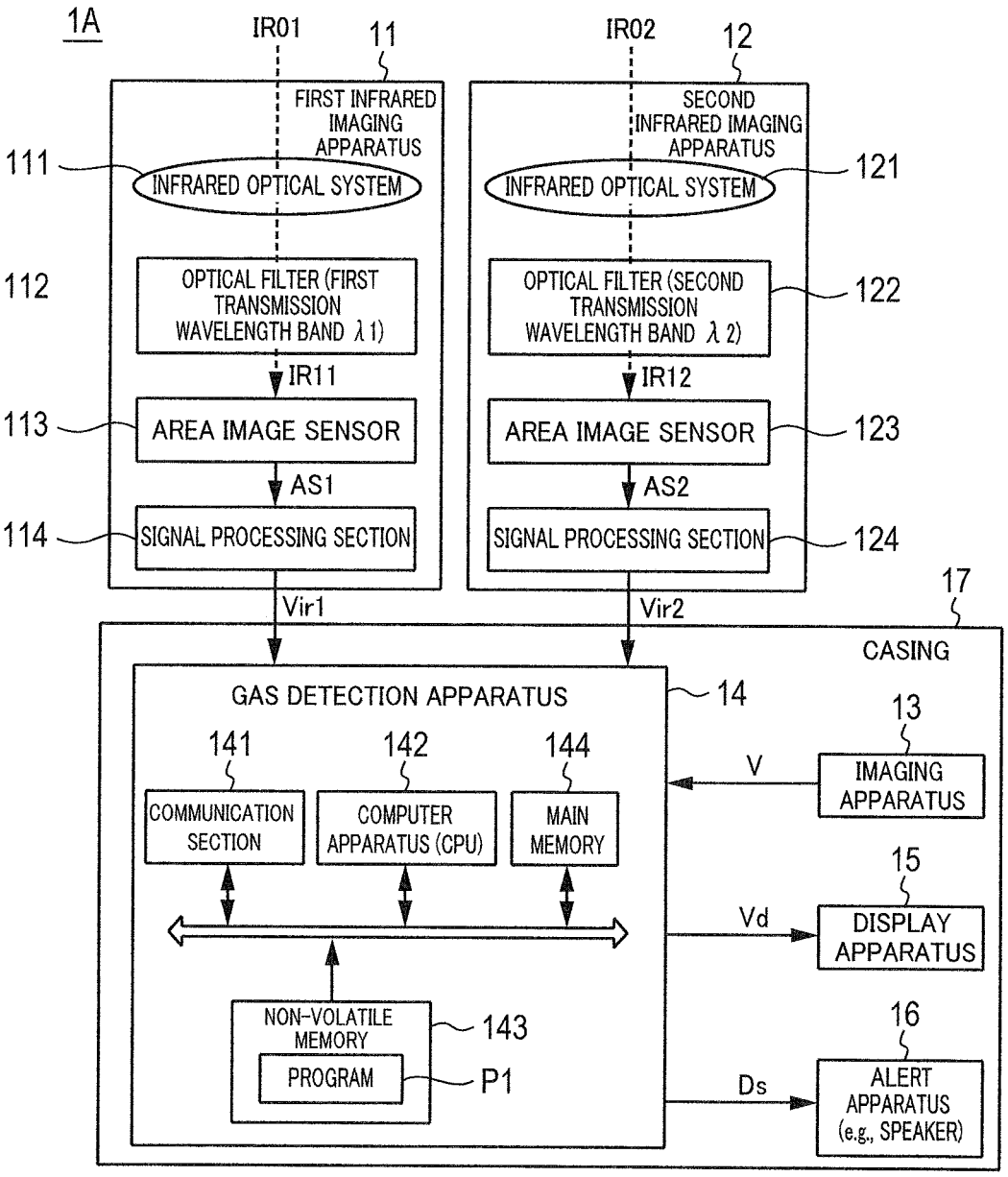

1A
IR01
11
FIRST INFRARED IMAGING APPARATUS
111
INFRARED OPTICAL SYSTEM
112
OPTICAL FILTER (FIRST TRANSMISSION WAVELENGTH BAND λ1)
IR11
113
AREA IMAGE SENSOR
AS1
114
SIGNAL PROCESSING SECTION
IR02
12
SECOND INFRARED IMAGING APPARATUS
121
INFRARED OPTICAL SYSTEM
122
OPTICAL FILTER (SECOND TRANSMISSION WAVELENGTH BAND λ2)
IR12
123
AREA IMAGE SENSOR
AS2
124
SIGNAL PROCESSING SECTION
Vir1
Vir2
17
CASING
GAS DETECTION APPARATUS
14
141
142
144
COMMUNICATION SECTION
COMPUTER APPARATUS (CPU)
MAIN MEMORY
NON-VOLATILE MEMORY
143
PROGRAM
P1
V
13
IMAGING APPARATUS
Vd
15
DISPLAY APPARATUS
Ds
16
ALERT APPARATUS (e.g., SPEAKER)

FIG. 1

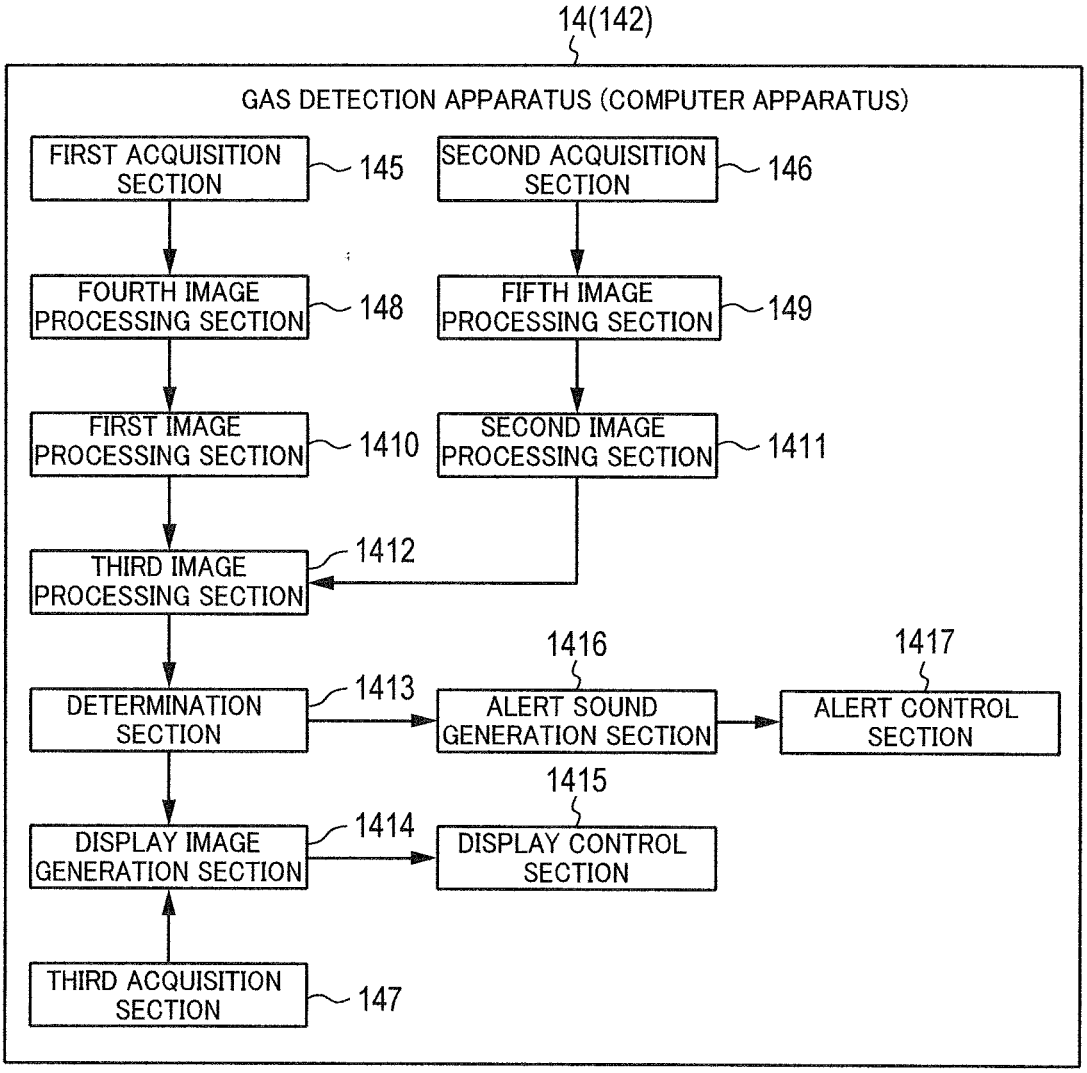

14(142)
GAS DETECTION APPARATUS (COMPUTER APPARATUS)
FIRST ACQUISITION SECTION
145
SECOND ACQUISITION SECTION
146
FOURTH IMAGE PROCESSING SECTION
148
FIFTH IMAGE PROCESSING SECTION
149
FIRST IMAGE PROCESSING SECTION
1410
SECOND IMAGE PROCESSING SECTION
1411
THIRD IMAGE PROCESSING SECTION
1412
1416
1417
DETERMINATION SECTION
1413
ALERT SOUND GENERATION SECTION
ALERT CONTROL SECTION
1415
DISPLAY IMAGE GENERATION SECTION
1414
DISPLAY CONTROL SECTION
THIRD ACQUISITION SECTION
147

FIG. 2

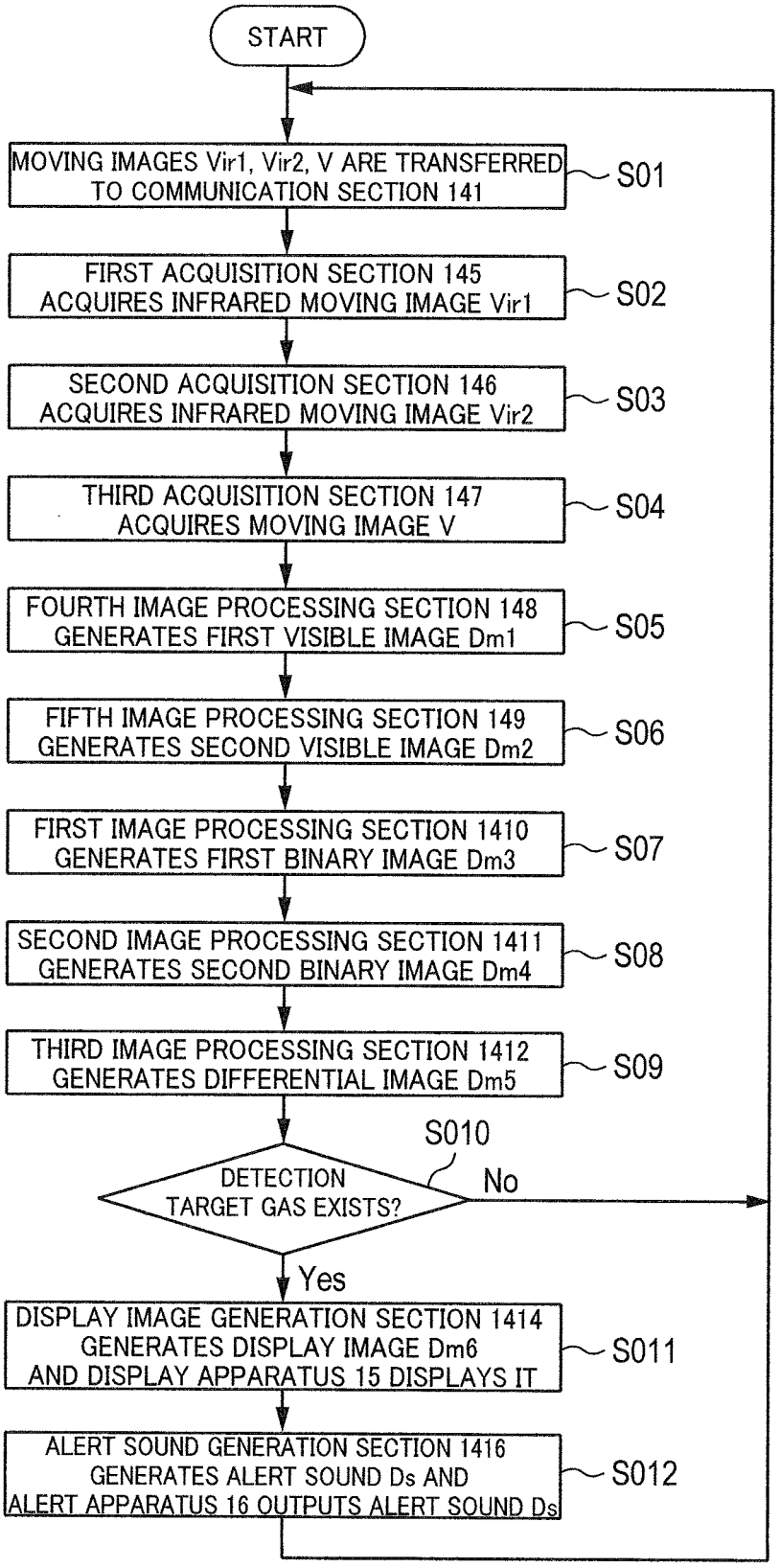

START
MOVING IMAGES Vir1, Vir2, V ARE TRANSFERRED TO COMMUNICATION SECTION 141
S01
FIRST ACQUISITION SECTION 145 ACQUIRES INFRARED MOVING IMAGE Vir1
S02
SECOND ACQUISITION SECTION 146 ACQUIRES INFRARED MOVING IMAGE Vir2
S03
THIRD ACQUISITION SECTION 147 ACQUIRES MOVING IMAGE V
S04
FOURTH IMAGE PROCESSING SECTION 148 GENERATES FIRST VISIBLE IMAGE Dm1
S05
FIFTH IMAGE PROCESSING SECTION 149 GENERATES SECOND VISIBLE IMAGE Dm2
S06
FIRST IMAGE PROCESSING SECTION 1410 GENERATES FIRST BINARY IMAGE Dm3
S07
SECOND IMAGE PROCESSING SECTION 1411 GENERATES SECOND BINARY IMAGE Dm4
S08
THIRD IMAGE PROCESSING SECTION 1412 GENERATES DIFFERENTIAL IMAGE Dm5
S09
S010
DETECTION TARGET GAS EXISTS?
No
Yes
DISPLAY IMAGE GENERATION SECTION 1414 GENERATES DISPLAY IMAGE Dm6 AND DISPLAY APPARATUS 15 DISPLAYS IT
S011
ALERT SOUND GENERATION SECTION 1416 GENERATES ALERT SOUND Ds AND ALERT APPARATUS 16 OUTPUTS ALERT SOUND Ds
S012

FIG. 3

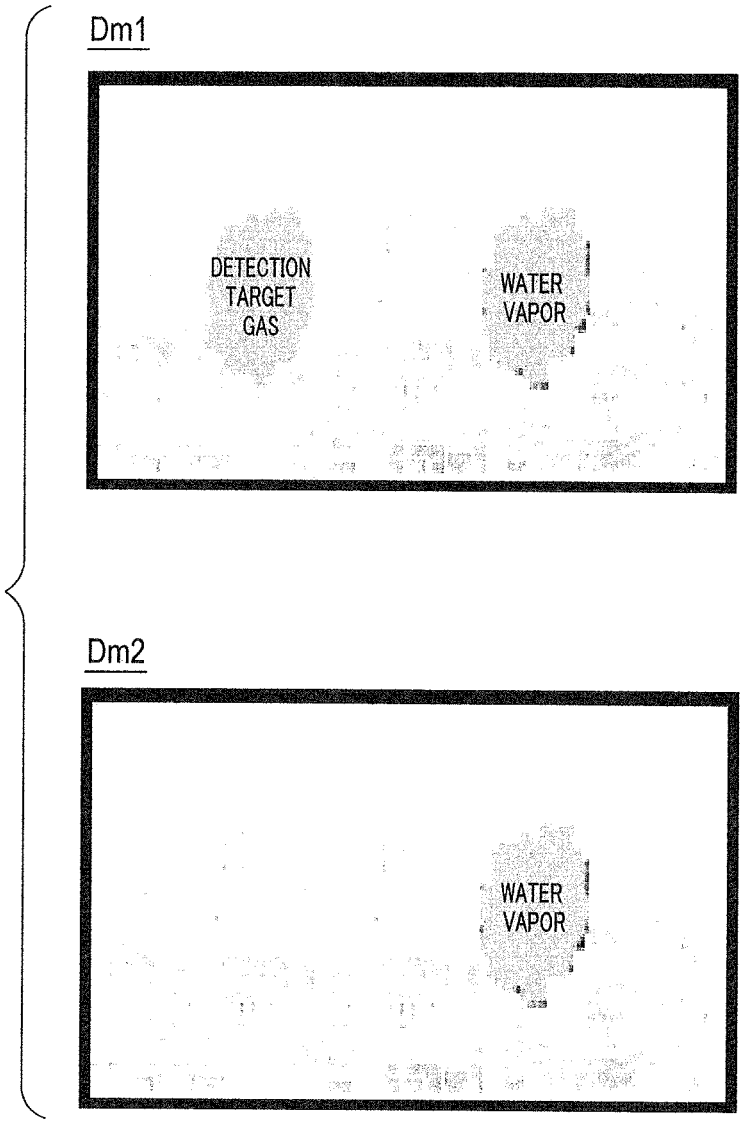


FIG. 4

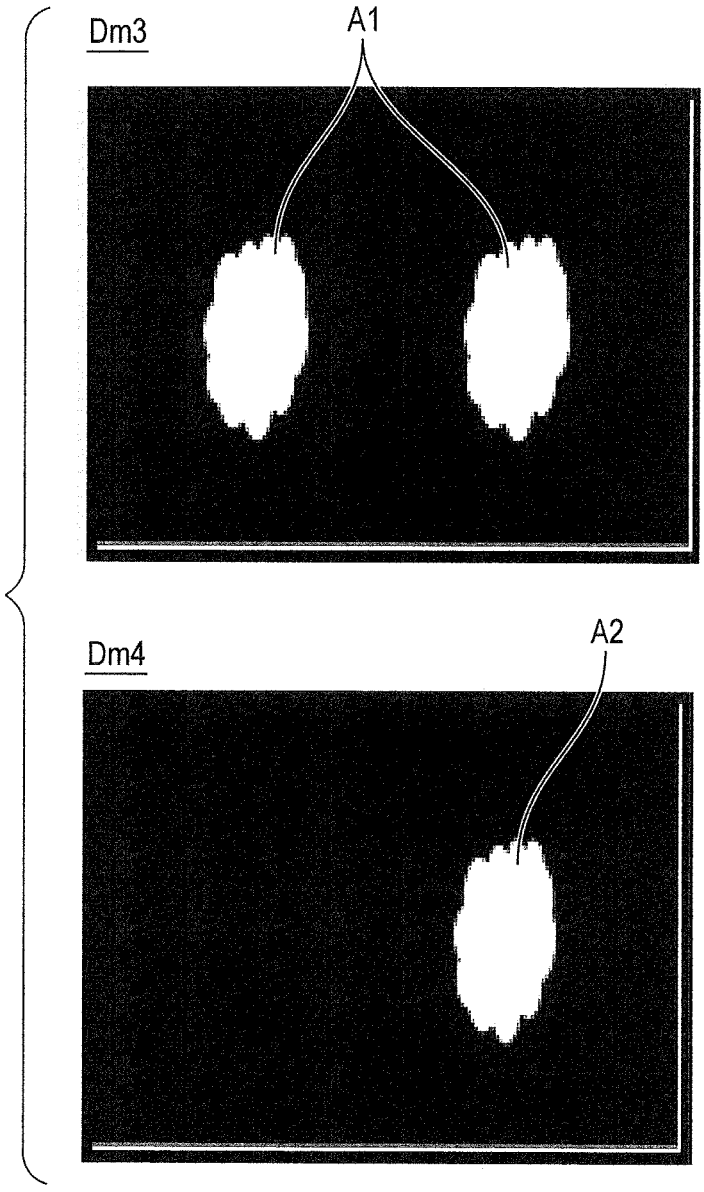


FIG. 5

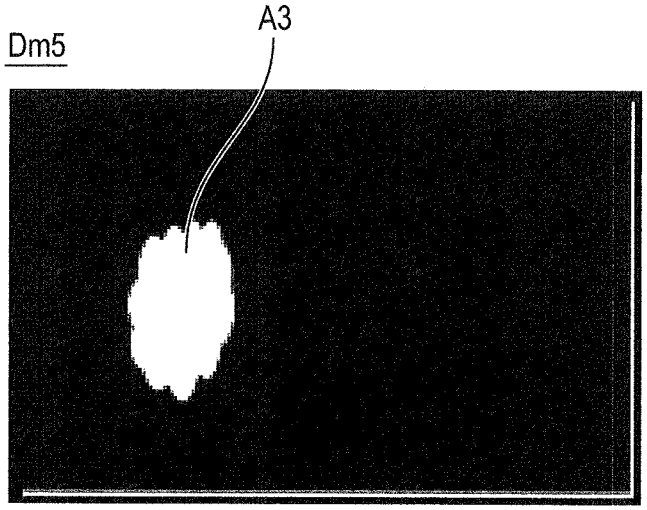
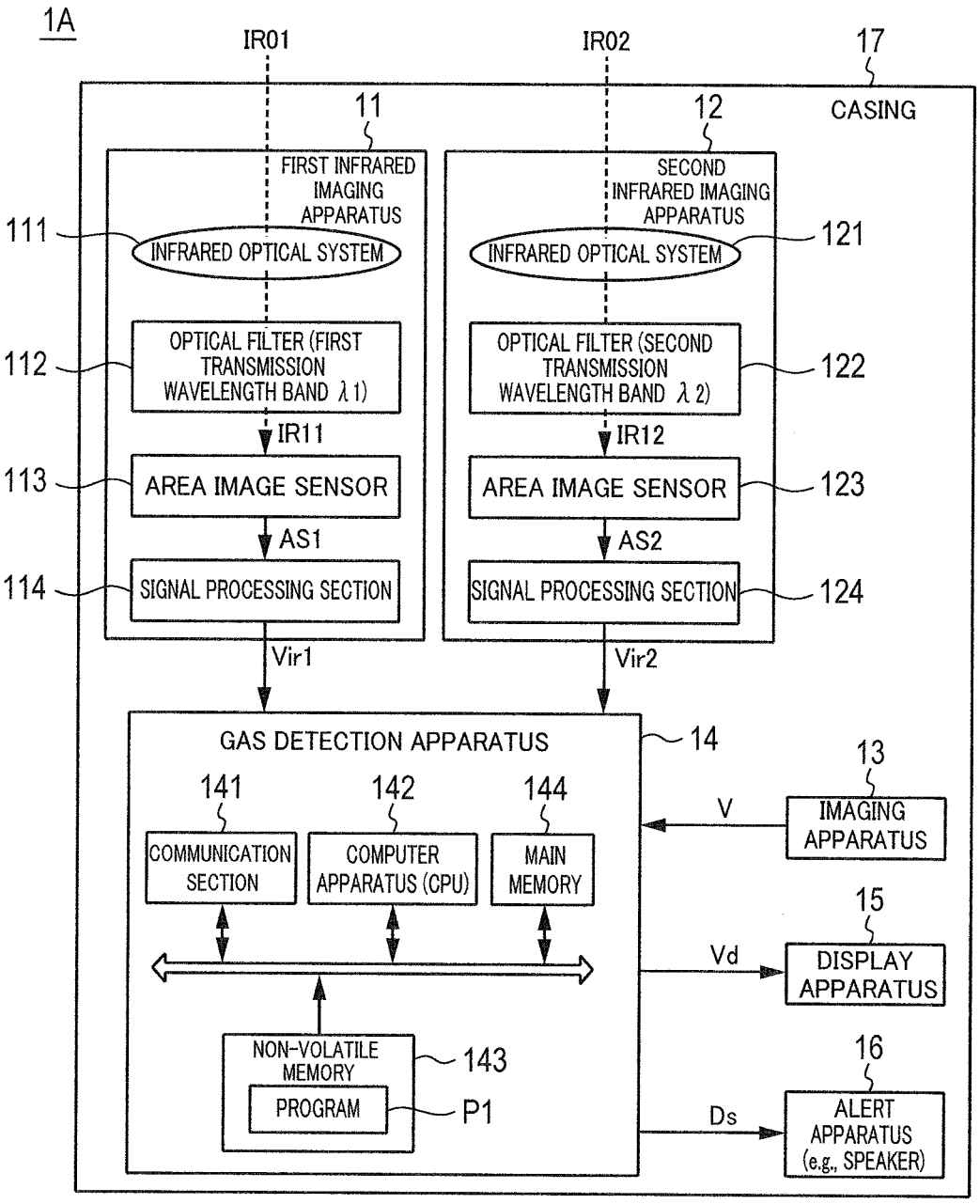


FIG. 6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OPTICAL FILTER (SECOND TRANSMISSION WAVELENGTH BAND λ2)
IR11
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AREA IMAGE SENSOR
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COMPUTER APPARATUS (CPU)
MAIN MEMORY
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Vd
DISPLAY APPARATUS
NON-VOLATILE MEMORY
143
16
PROGRAM
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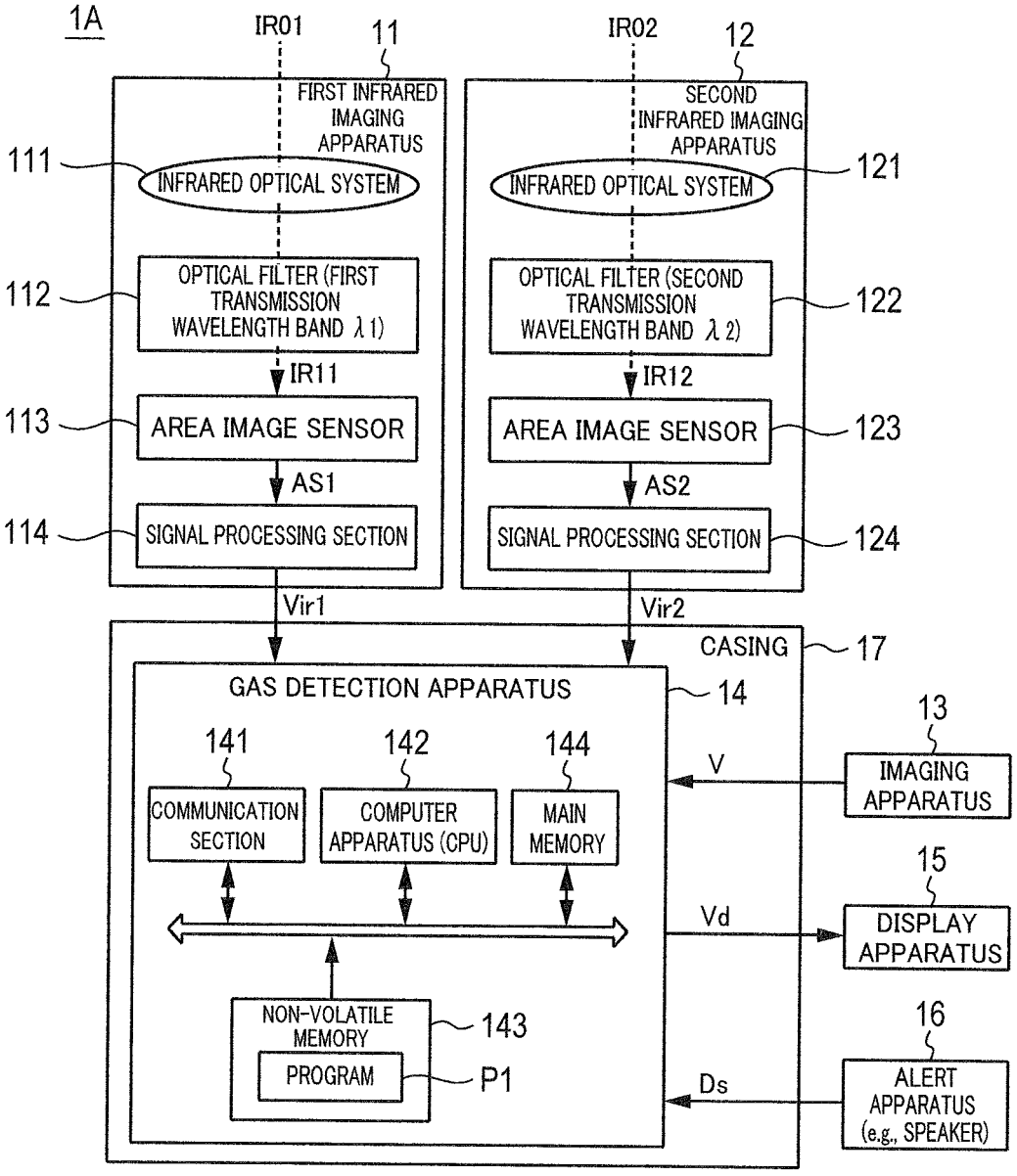
Ds
ALERT APPARATUS (e.g., SPEAKER)

FIG. 7


1A
IR01
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IR02
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FIRST INFRARED IMAGING APPARATUS
SECOND INFRARED IMAGING APPARATUS
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INFRARED OPTICAL SYSTEM
INFRARED OPTICAL SYSTEM
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OPTICAL FILTER (FIRST TRANSMISSION WAVELENGTH BAND λ1)
OPTICAL FILTER (SECOND TRANSMISSION WAVELENGTH BAND λ2)
122
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IR12
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123
AS1
AS2
114
SIGNAL PROCESSING SECTION
SIGNAL PROCESSING SECTION
124
Vir1
Vir2
CASING
17
GAS DETECTION APPARATUS
14
13
141
142
144
V
IMAGING APPARATUS
COMMUNICATION SECTION
COMPUTER APPARATUS (CPU)
MAIN MEMORY
15
Vd
DISPLAY APPARATUS
NON-VOLATILE MEMORY
143
16
PROGRAM
P1
Ds
ALERT APPARATUS (e.g., SPEAKER)

FIG. 8

GAS DETECTION DEVICE, GAS DETECTION METHOD, AND GAS DETECTION PROGRAM

TECHNICAL FIELD

[0001] The present invention relates to a gas detection apparatus, a gas detection method and a gas detection program that determine an area of a gas to be detected (hereinafter referred to as a "detection target gas") in a monitoring area, using infrared images.

BACKGROUND ART

[0002] Conventionally, as a gas detection apparatus such as above, for example, there is the gas monitoring apparatus described in PTL 1 indicated below.

[0003] In the gas monitoring apparatus described in PTL 1, an infrared monitoring camera takes an image of infrared rays radiated or infrared rays reflected from the monitoring area, and includes a tunable filter that can change a transmission spectrum thereof. An image processing apparatus calculates a difference between an image taken with the tunable filter adjusted so as to have a transmission peak at one of absorption bands of a particular detection target gas (hereinafter referred to as a "first image") and an image taken with the tunable filter adjusted so as to have a transmittance peak near the absorption band thereof (hereinafter referred to as a "second image"). Subsequently, the image processing apparatus generates a differential image including, as an image of the gas, a pixel area in which infrared rays radiated or infrared rays reflected from the background of the monitoring area have been absorbed by the detection target gas.

CITATION LIST

Patent Literature

[0004] PTL 1: Japanese Patent Application Laid-Open No. 2001-349829

SUMMARY OF INVENTION

Technical Problem

[0005] However, differential images in conventional gas monitoring apparatuses have the problem of containing much noise. Specifically, pixel values indicating the background may be different between a first image and a second image because of a difference in transmitted wavelengths from the tunable filter. Furthermore, a difference in background image may occur between a first image and a second image due to, e.g., a disparity between infrared monitoring cameras and/or movement of an infrared monitoring camera. When a difference is calculated between such first and second images, a problem is that pixel values indicating the background part are visualized as noise, in addition to a detection target gas in a result of the calculation.

[0006] Therefore, an object of the present invention is to provide a gas detection apparatus, a gas detection method and a gas detection program that enable noise reduction.

Solution to Problem

[0007] In order to achieve the above object, according to a first aspect of the present invention is directed to a gas detection apparatus including: a first acquisition section that acquires a first image generated using a first optical filter having a first transmission wavelength band that is a wavelength band including at least an absorption wavelength band of a gas to be detected in a monitoring area; a second acquisition section that acquires a second image generated using a second optical filter having a second transmission wavelength band, the second transmission wavelength band being a wavelength band that is different from the absorption wavelength band; a first image processing section that generates a first binary image indicating an inside and an outside of each of respective first areas indicating the gas and water vapor, by binary values, based on the first image; a second image processing section that generates a second binary image indicating an inside and an outside of a second area indicating the water vapor, by binary values, based on the second image; and a third image processing section that calculates a difference between the first binary image and the second binary image.

[0008] In order to achieve the above object, according to a second aspect of the present invention is directed to a gas detection method comprising: a first acquisition step of acquiring a first image generated using a first optical filter having a first transmission wavelength band that is a wavelength band including at least an absorption wavelength band of a gas to be detected in a monitoring area; a second acquisition step of acquiring a second image generated using a second optical filter having a second transmission wavelength band, the second transmission wavelength band being a wavelength band that is different from the absorption wavelength band; a first image processing step of generating a first binary image indicating an inside and an outside of each of respective first areas indicating the gas and water vapor, by binary values, based on the first image; a second image processing step of generating a second binary image indicating an inside and an outside of a second area indicating the water vapor, by binary values, based on the second image; and a third image processing step of calculating a difference between the first binary image and the second binary image.

[0009] In order to achieve the above object, according to a third aspect of the present invention is directed to a gas detection program for causing a computer to function as: a first acquisition section that acquires a first image generated using a first optical filter having a first transmission wavelength band that is a wavelength band including at least an absorption wavelength band of a gas to be detected in a monitoring area; a second acquisition section that acquires a second image generated using a second optical filter having a second transmission wavelength band, the second transmission wavelength band being a wavelength band that is different from the absorption wavelength band; a first image processing section that generates a first binary image indicating an inside and an outside of each of respective first areas indicating the gas and water vapor, by binary values, based on the first image; a second image processing section that generates a second binary image indicating an inside and an outside of a second area indicating the water vapor, by binary values, based on the second image; and a third image processing section that calculates a difference between the first binary image and the second binary image.

Advantageous Effects of Invention

[0010] The above aspects enable provision of a gas detection apparatus, a gas detection method and a gas detection program that enable noise reduction.

BRIEF DESCRIPTION OF DRAWINGS

[0011] FIG. **1** is a diagram illustrating a hardware configuration of a gas monitoring system, which is an example application of a gas detection apparatus according to an embodiment of the present invention;

[0012] FIG. **2** is a function block diagram illustrating the computer apparatus in FIG. **1**;

[0013] FIG. **3** is a flowchart illustrating operation of a gas monitor according to Embodiment 1, the flowchart indicating a procedure of a gas visualization method and a gas visualization program according to Embodiment 1;

[0014] FIG. **4** is a diagram illustrating a first visible image and a second visible image;

[0015] FIG. **5** is a diagram illustrating a first binary image and a second binary image;

[0016] FIG. **6** is a diagram illustrating a differential image;

[0017] FIG. **7** is a diagram illustrating a hardware configuration of a gas monitoring system according to a first alteration; and

[0018] FIG. **8** is a diagram illustrating a hardware configuration of a gas monitoring system according to a second alteration.

DESCRIPTION OF EMBODIMENTS

1. Embodiment 1

[0019] Gas monitoring system **1**A to which a gas detection apparatus, a gas detection method and a gas detection program according to an embodiment of the present invention are applied will be described in detail below with reference to the accompanying drawings.

[0020] <<1-1. Example Configuration of Gas Monitoring System>>

[0021] In FIG. **1**, gas monitoring system **1**A includes first infrared imaging apparatus **11**, second infrared imaging apparatus **12**, imaging apparatus **13**, gas detection apparatus **14**, display apparatus **15** and alert apparatus **16**. In the present embodiment, gas detection apparatus **14**, display apparatus **15** and alert apparatus **16** are housed inside same casing **17**, and first infrared imaging apparatus **11**, second infrared imaging apparatus **12** and imaging apparatus **13** are connected to gas detection apparatus **14** via any of a communication network, a wired transmission channel and a radio link.

[0022] Infrared imaging apparatuses **11**, **12** are installed at respective positions from which an area to be monitored for leakage of a gas invisible to the naked eye (hereinafter referred to as a "detection target gas") (hereinafter referred to as a "monitoring area") can be observed. It is preferable that infrared imaging apparatuses **11**, **12** be installed adjacent to each other to reduce a disparity therebetween. Infrared imaging apparatuses **11**, **12** include infrared optical systems **111**, **121**, optical filters **112**, **122**, area image sensors (two-dimensional image sensors) **113**, **123** and signal processing sections **114**, **124**, respectively.

[0023] Infrared optical systems **111**, **121** output infrared rays IR**01**, IR**02** radiated from the monitoring area, which is a subject, to optical filters **112**, **122** in order to form images on area image sensors **113**, **123**, respectively.

[0024] Optical filter **112** is disposed on an optical path between infrared optical system **111** and area image sensor **113**, and has first transmission wavelength band λ**1** that is a wavelength band including at least an absorption wavelength band of the detection target gas. Optical filter **112** lets infrared rays IR**11** through, infrared rays IR**11** being included in first transmission wavelength band λ**1**, from among infrared rays IR**01** passed through infrared optical system **111**. Here, if infrared rays IR**01** are ones passed through the detection target gas, no components in the absorption wavelength band of the detection target gas enter optical filter **112**. Conversely, if no detection target gas exists in the monitoring area, infrared rays IR**01** contain components in the absorption wavelength band of the detection target gas. Based on whether or not there are components in the absorption wavelength band, gas monitoring system **1**A detects whether or not the detection target gas exists. For example, where first transmission wavelength band λ**1** is a medium wavelength band of 3.2 μm to 3.4 μm, gases indicated in the right side of the upper part of Table 1 can be detected. Also, where first transmission wavelength band λ**1** is a long wavelength band, gases indicated in the right side of the lower part of Table 1 can be detected.

TABLE 1

First transmission wavelength bands and detection target gas types

First transmission wavelength band λ1	Detection target gases
3.2 μm to 3.4 μm	butane gas
	methyl ethyl ketone
	benzene
	ethane
	methyl isobutyl ketone
	ethanol
	methane
	octane
	ethyl benzene
	propane
	pentane
	heptane
	ethylene
	1-pentane
	hexane
	propylene
	toluene
	isoprene
	xylene
	methanol
10 μm to 11 μm	SF6 (sulfur hexafluoride)
	anhydrous ammonia
	ethyl cyanoacrylate
	chlorine dioxide
	acetic acid
	CFC-12
	ethylene
	methyl ethyl ketone (MEK)

[0025] Optical filter **122** is disposed on an optical path between infrared optical system **121** and area image sensor **123**, and lets infrared rays IR**12** through, infrared rays IR**12** being included in second transmission wavelength band λ**2** from among infrared rays IR**02** passed through infrared optical system **121**. Here, second transmission wavelength band λ**2** is set outside of first transmission wavelength band λ**1**. Preferably, second transmission wavelength band λ**2** is adjacent to first transmission wavelength band λ**1** with no

overlap therebetween. For example, if first transmission wavelength band λ**1** has a range of 3.2 μm to 3.4 μm, second transmission wavelength band λ**2** is set to have a range of 3.5 μm to 3.7 μm. Also, if first transmission wavelength band λ**1** has a range of 10 μm to 11 μm, second transmission wavelength band λ**2** is set to have a range of 12 μm to 13 μm.

[0026] Area image sensors **113**, **123** perform photoelectric conversion of infrared rays IR**11**, IR**12** passed through optical filters **112**, **122** to generate electric analog signals AS**1**, AS**2** representing infrared images (thermal images) of the monitoring area, and output electric analog signals AS**1**, AS**2**, respectively. A principle of operation and a material of area image sensors **113**, **123** are properly selected according to first transmission wavelength band λ**1**. More specifically, if first transmission wavelength band λ**1** ranges from 3.2 μm to 3.4 μm, a sensor such as a cooled indium antimonide image sensor is used, and if first transmission wavelength band λ**1** ranges 10 μm to 11 μm, a sensor such as a cooled QWIP (quantum well infrared detector element) is used.

[0027] In the below, the description will be continued assuming that the detection target gas is methane.

[0028] Signal processing sections **114**, **124** receive analog signals AS**1**, AS**2** from area image sensors **113**, **123**, convert analog signals AS**1**, AS**2** into digital signals and thereby generate infrared moving images Vir**1**, Vir**2**, respectively. At this time, signal processing sections **114**, **124** may perform known image processing as necessary. Signal processing sections **114**, **124** sequentially output generated infrared moving images Vir**1**, Vir**2** to gas detection apparatus **14** via the communication network at a predetermined frame rate, respectively. Here, infrared moving images Vir**1**, Vir**2** are respective examples of a first infrared image and a second infrared image, and represent infrared energy radiated from the monitoring area, for example, with a 256-level gray scale.

[0029] Imaging apparatus **13** is installed at a position from which the monitoring area can be observed, near infrared imaging apparatuses **11**, **12**. Imaging apparatus **13** takes a moving image V (or a still image) representing the monitoring area, moving image V (or the still image) being formed of visible image frames (or a visible image frame), and transfers moving image V (or the still image) to gas detection apparatus **14** via, e.g., the communication network.

[0030] Gas detection apparatus **14** includes communication section **141**, CPU **142**, which is a typical example of a computer apparatus, non-volatile memory **143** and main memory **144**.

[0031] Communication section **141** is a communication interface between gas detection apparatus **14** and other apparatuses **11**, **12**, **13**, **15**, **16**.

[0032] CPU **142** executes program P**1** stored in advance in non-volatile memory **143**, using main memory **144** as a work area. Consequently, as illustrated in FIG. **2**, CPU **142** functions as first acquisition section **145**, second acquisition section **146**, third acquisition section **147**, fourth image processing section **148**, fifth image processing section **149**, first image processing section **1410**, second image processing section **1411**, third image processing section **1412**, determination section **1413**, display image generation section **1414**, display control section **1415**, alert sound generation section **1416** and alert control section **1417**.

[0033] Display apparatus **15** is, for example, a liquid-crystal display, and displays display image Vd generated by gas detection apparatus **14**.

[0034] Alert apparatus **16** is, for example, a speaker, and outputs alert sound Ds generated by gas detection apparatus **14**.

[0035] <<1-2. Operation of Gas Monitoring System>>

[0036] Next, operation of gas monitoring system **1**A will be described, in particular, with operation of gas detection apparatus **14** focused on, with reference to, e.g., FIG. **3**.

[0037] First, in step S**01** in FIG. **3**, respective frames forming infrared moving images Vir**1**, Vir**2** and moving image V are sequentially transferred to communication section **141** of gas detection apparatus **14**.

[0038] In next steps S**02**, S**03**, first acquisition section **145** and second acquisition section **146** (CPU **142**) sequentially store infrared moving images Vir**1**, Vir**2** transferred to communication section **141**, in main memory **144** on a frame-by-frame basis, respectively. Consequently, acquisition sections **145**, **146** acquire infrared moving images Vir**1**, Vir**2**, respectively.

[0039] In next step S**04**, third acquisition section **147** sequentially stores moving image V in main memory **144** on a frame-by-frame basis.

[0040] In next step S**05**, fourth image processing section **148** (CPU **142**) detects moving objects from each frame included in infrared moving image Vir**1** by means of a background differencing technique or an optical-flow technique, and generates first visible image Dm**1**.

[0041] In the background differencing technique, a first reference image taken by infrared imaging apparatus **11** in a state in which neither the detection target gas nor water vapor exists in the monitoring area is stored in advance in, e.g., non-volatile memory **143**. Fourth image processing section **148** calculates a difference between each frame included in infrared moving image Vir**1** and the first reference image to generate first visible image Dm**1** in which the moving object in the monitoring area is visualized. Here, optical filter **121** has first transmission wavelength band λ**1** including the absorption wavelength band of the detection target gas, and thus, if the detection target gas exists in the monitoring area, as illustrated in the upper part of FIG. **4**, the detection target gas is visualized as a moving object in first visible image Dm**1**. Also, water vapor partly absorbs infrared rays radiated from the background, but re-radiates infrared rays in a wide band depending on, e.g., the temperature of the water vapor. Therefore, if water vapor exists, optical filter **121** lets infrared rays through, the infrared rays being included in the transmission wavelength band of optical filter **121** from among the infrared rays radiated by the water vapor. Therefore, in first visible image Dm**1**, water vapor is also visualized as a moving object.

[0042] In the optical-flow technique, fourth image processing section **148** vectorially estimates movements of moving objects in the monitoring area, using the plurality of frames forming infrared moving image Vir**1**. Therefore, as in the above, if the detection target gas and/or water vapor exist in the monitoring area, the detection target gas and/or the water vapor are visualized as moving object(s) in first visible image Dm**1**.

[0043] In next step S**06**, with a method similar to that of fourth image processing section **148**, fifth image processing section **149** (CPU **142**) detects moving objects from each frame included in infrared moving image Vir**2** and generates

second visible image Dm**2**. Here, infrared moving image Vir**2** is generated using optical filter **122** having transmission wavelength band λ**2**. Therefore, even if the detection target gas exists in the monitoring area, as illustrated in the lower part of FIG. **4**, in second visible image Dm**2**, the detection target gas is not visualized as a moving object. However, water vapor is visualized also in second visible image Dm**2** for a reason that is similar to the above.

[0044] Here, in each of steps S**05**, S**06**, it is preferable that an absolute value of the difference be calculated in order to respond to high-temperature water vapor or low-temperature water vapor.

[0045] In next step S**07**, first image processing section **1410** (CPU **142**) performs binarization processing of first visible image Dm**1** to generate first binary image Dm**3**. More specifically, in first visible image Dm**1**, each pixel value indicating any of the detection target gas and water vapor has, for example, a large value. On the other hand, since first visible image Dm**1** is generated by means of, e.g., the background differencing technique, in first visible image Dm**1**, each pixel value indicating a background part of the detection target gas and the water vapor has a relatively small value. In program P**1**, a threshold value for distinguishing between the detection target gas and the water vapor, and the background part is derived in advance by, e.g., tests conducted at the design and development stage of gas detection apparatus **14**. First image processing section **1410** compares each pixel value of first visible image Dm**1** with the threshold value to set values of all of the pixels indicating the detection target gas and the water vapor to, for example, either one of "0" and "255" and set values of all of the pixels indicating the background part to the other. As a result of the above processing, as illustrated in the upper part in FIG. **5**, first binary image Dm**3** indicating the inside of each of respective first pixel areas A**1** indicating the detection target gas and the water vapor and the outside of each of the first pixel areas A**1**, the outside indicating the background part, by binary values, is generated.

[0046] In next step S**08**, second image processing section **1411** (CPU **142**) performs binarization processing of second visible image Dm**2** to generate second binary image Dm**4**. This processing is performed in a manner that is the same as that in step S**07**. As a result, as illustrated in the lower part of FIG. **5**, second binary image Dm**4** indicating the inside of second pixel area A**2** indicating the water vapor and the outside of second pixel area A**2**, the outside indicating the background part, by binary values, is generated.

[0047] In next step S**09**, third image processing section **1412** (CPU **142**) calculates a difference between first binary image Dm**3** and second binary image Dm**4**. If the detection target gas exists in the monitoring area, as illustrated in FIG. **6**, the calculated difference is differential image Dm**5** indicating the inside of third pixel area A**3** indicating the detection target gas and the outside of the third pixel area A**3**, the outside being a part other than the detection target gas, by binary values.

[0048] In next step S**010**, determination section **1413** determines whether or not any pixel value indicating the detection target gas (that is, either one of "0" and "255") exists in differential image Dm**5**. If determination section **1413** makes determination of Yes, determination section **1413** considers the detection target gas as existing in the monitoring area, and performs steps S**010**, S**011**. On the other hand, if determination section **1413** makes determination of No, determination section **1413** considers no detection target gas as existing and returns to S**01** without performing steps S**010**, S**011**.

[0049] In step S**011**, display image generation section **1414** superimposes differential image Dm**5** for each frame of moving image V on the frame to generates display moving image Vd. Subsequently, display control section **1415** transfers display moving image Vd to display apparatus **15**, and display apparatus **15** displays received moving image Vd. A user views moving image Vd and thereby recognizes leakage of the detection target gas in the monitoring area.

[0050] Also, in step S**012**, alert sound generation section **1416** generates alert sound Ds, and alert apparatus **16** outputs generated alert sound Ds under the control of alert sound control section **1417**. The output of alert sound Ds also enables the user to recognize leakage of the detection target gas in the monitoring area.

[0051] <<1-3. Effects>>

[0052] As above, in steps S**07**, S**08**, CPU **142** generates binary images Dm**3**, Dm**4**, respectively. In binary images Dm**3**, Dm**4**, pixel areas A**1**, A**2** indicating the background part are subjected to replacement so as to have a single value. Therefore, noise is less likely to occur in the background part of differential image Dm**5** generated based on binary images Dm**3**, Dm**4**. In other words, differential image Dm**5** can clearly define third pixel area A**3** indicating the detection target gas.

[0053] Also, in step S**010**, CPU **142** can correctly determine whether or not the detection target gas exists because of use of differential image Dm**5** described above.

[0054] Also, in step S**011**, CPU **142** superimposes differential image Dm**5** on moving image V, and thus, low-noise display moving image Vd is displayed on display apparatus **15**. Accordingly, a user can correctly determine whether or not the detection target gas exists, by viewing display moving image Vd.

[0055] Also, in step S**010**, CPU **142** can correctly determine whether or not the detection target gas exists, and thus the user can also correctly determine whether or not the detection target gas exists, based on alert sound Ds.

[0056] <<1-4. Alteration>>

[0057] Gas monitoring system **1**A in FIG. **1** has been described as one in which: first infrared imaging apparatus **11**, second infrared imaging apparatus **12** and imaging apparatus **13** are connected to gas detection apparatus **14** via a communication network; and gas detection apparatus **14**, display apparatus **15** and alert apparatus **16** are incorporated in same casing **17**. However, the present invention is not limited to this example, and as illustrated in FIG. **7**, gas monitoring system **1**A may incorporate first infrared imaging apparatus **11**, second infrared imaging apparatus **12**, imaging apparatus **13**, gas detection apparatus **14**, display apparatus **15** and alert apparatus **16** in same casing **17**. Also, as illustrated in FIG. **8**, gas detection apparatus **14** may be connected to each of first infrared imaging apparatus **11**, second infrared imaging apparatus **12**, imaging apparatus **13**, display apparatus **15** and alert apparatus **16** via a communication network. Here, in each of the cases in FIGS. **7** and **8**, operation and processing in each component are as described above.

[0058] <<1-5. Supplement **1**>>

[0059] The above embodiment has been described in terms of the case where gas monitoring system **1**A includes

second infrared imaging apparatus **12**. As described above, it is sufficient that second infrared imaging apparatus **12** includes optical filter **122** having transmission wavelength band λ**2** outside of absorption wavelength band λ**1**. Here, transmission wavelength band λ**2** is not limited to an infrared wavelength band. In other words, gas monitoring system **1**A may include an imaging apparatus that can take a visible image, instead of second infrared imaging apparatus **12**.

[0060] <<1-6. Supplement **2**>>

[0061] The above embodiment has been described in terms of the case where alert apparatus **16** is a speaker that outputs alert sound Ds. However, the present invention is not limited to this case, alert apparatus **16** may alert a user to existence of a detection target gas by means of light or vibration.

[0062] <<1-7. Supplement **3**>>

[0063] The above embodiment has been described in terms of the case where gas monitoring system **1**A includes two infrared imaging apparatuses **11**, **12**. However, functions similar to those of two infrared imaging apparatuses **11**, **12** can be provided by a single infrared imaging apparatus alone. In other words, this infrared imaging apparatus selectively switches between optical filters **112** and **122** to generate infrared moving images Vir**1**, Vir**2** time-divisionally, and transfers infrared moving images Vir**1**, Vir**2** to gas detection apparatus **14**.

[0064] <<1-8. Supplement **4**>>

[0065] Also, program P**1** described above may be provided not only in a state in which program P**1** is stored in non-volatile memory **123**, but also via a recording medium such as a DVD (digital versatile disc) or a communication network.

[0066] The entire disclosure of the description, the drawings and the abstract included in Japanese Patent Application No. 2016-009885 filed on Jan. 21, 2016 is incorporated herein.

INDUSTRIAL APPLICABILITY

[0067] The gas detection apparatus, the gas detection method and the gas detection program according to the present invention enable noise reduction and are thus suitable for, e.g., a gas monitoring system.

REFERENCE SIGNS LIST

[0068] **1**A gas monitoring system
[0069] **11** first infrared imaging apparatus
[0070] **12** second infrared imaging apparatus
[0071] **13** imaging apparatus
[0072] **14** gas detection apparatus
[0073] **142** computer apparatus (CPU)
[0074] P**1** program
[0075] **145** first acquisition section
[0076] **146** second acquisition section
[0077] **1410** first image processing section
[0078] **1411** second image processing section
[0079] **1412** third image processing section
[0080] **1413** determination section
[0081] **15** display apparatus
[0082] **16** alert apparatus

1. A gas detection apparatus comprising:

a hardware processor that:

acquires a first image generated using a first optical filter having a first transmission wavelength band that is a wavelength band including at least an absorption wavelength band of a gas to be detected in a monitoring area;

acquires a second image generated using a second optical filter having a second transmission wavelength band, the second transmission wavelength band being a wavelength band that is different from the absorption wavelength band;

generates a first binary image indicating an inside and an outside of each of respective first areas indicating the gas and water vapor, by binary values, based on the first image;

generates a second binary image indicating an inside and an outside of a second area indicating the water vapor, by binary values, based on the second image; and

calculates a difference between the first binary image and the second binary image.

2. The gas detection apparatus according to claim **1**, wherein the hardware processor determines whether or not the gas exists in the monitoring area, based on the difference.

3. The gas detection apparatus according to claim **1**, further comprising a display apparatus that displays a display image in which a third area indicating the gas is visualized based on the difference.

4. The gas detection apparatus according to claim **1**, further comprising an alert apparatus that provides alert of existence of the gas in the monitoring area, based on the difference.

5. The gas detection apparatus according to claim **1**, wherein the hardware processor defines the first areas and the second area based on either of a background differencing technique and an optical-flow technique.

6. A gas detection method comprising:

acquiring a first image generated using a first optical filter having a first transmission wavelength band that is a wavelength band including at least an absorption wavelength band of a gas to be detected in a monitoring area;

acquiring a second image generated using a second optical filter having a second transmission wavelength band, the second transmission wavelength band being a wavelength band that is different from the absorption wavelength band;

generating a first binary image indicating an inside and an outside of each of respective first areas indicating the gas and water vapor, by binary values, based on the first image;

generating a second binary image indicating an inside and an outside of a second area indicating the water vapor, by binary values, based on the second image; and

calculating a difference between the first binary image and the second binary image.

7. A gas detection program for causing a computer to perform:

acquiring a first image generated using a first optical filter having a first transmission wavelength band that is a wavelength band including at least an absorption wavelength band of a gas to be detected in a monitoring area;

acquiring a second image generated using a second optical filter having a second transmission wavelength band, the second transmission wavelength band being a wavelength band that is different from the absorption wavelength band;

generating a first binary image indicating an inside and an outside of each of respective first areas indicating the gas and water vapor, by binary values, based on the first image;

generating a second binary image indicating an inside and an outside of a second area indicating the water vapor, by binary values, based on the second image; and

calculating a difference between the first binary image and the second binary image.

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