

US Patent & Trademark Office

Patent Public Search | Text View

United States Patent	12394088
Kind Code	B2
Date of Patent	August 19, 2025
Inventor(s)	Kikuchi; Hiroaki

Estimation apparatus, imaging apparatus, moving object, estimation system, estimation method, and program

Abstract

An estimation apparatus includes a processor, in which the processor is configured to acquire positional information of a plurality of reference stations each having a light emitter that emits light in wavelength bands different from each other, acquire image data obtained by imaging an imaging scene including the light emitter via an imaging apparatus mounted on a moving object, and estimate at least one of a position of the moving object or a posture of the moving object based on an in-image position, which is a position of the light emitter in an image indicated by the image data, and the positional information of the plurality of reference stations.

Inventors:	Kikuchi; Hiroaki (Kanagawa, JP)
Applicant:	FUJIFILM CORPORATION (Tokyo, JP)
Family ID:	1000008768263
Assignee:	FUJIFILM CORPORATION (Tokyo, JP)
Appl. No.:	18/599208
Filed:	March 08, 2024

Prior Publication Data

Document Identifier	Publication Date
US 20240212208 A1	Jun. 27, 2024

Foreign Application Priority Data

JP	2021-161787	Sep. 30, 2021
----	-------------	---------------

Related U.S. Application Data

Publication Classification

Int. Cl.: G06T7/73 (20170101)

U.S. Cl.:

CPC G06T7/74 (20170101); G06T2207/10032 (20130101); G06T2207/20224 (20130101)

Field of Classification Search

CPC: G06T (7/73); G06T (7/74); G06T (2207/10032); G06T (2207/20224); G01B (11/00); G01S (5/16); G05D (1/00)

USPC: 348/144

References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
12105200	12/2023	Onal	N/A	G01N 21/359
2017/0031369	12/2016	Liu et al.	N/A	N/A
2020/0288072	12/2019	Seok	N/A	H04N 23/88
2020/0342622	12/2019	Takeuchi	N/A	G06T 7/73
2022/0067942	12/2021	Ono	N/A	N/A

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
102018100417	12/2021	DE	F41G 3/145
2000-055657	12/1999	JP	N/A
2002-213920	12/2001	JP	N/A
2008-145386	12/2007	JP	N/A
2015-190931	12/2014	JP	N/A
2019-095963	12/2018	JP	N/A
2019-144183	12/2018	JP	N/A
2020-180842	12/2019	JP	N/A
2022-039246	12/2021	JP	N/A

OTHER PUBLICATIONS

International Search Report issued in International Application No. PCT/JP2022/020259 on Jul. 5, 2022. cited by applicant

Written Opinion of the ISA issued in International Application No. PCT/JP2022/020259 on Jul. 5, 2022. cited by applicant

International Preliminary Report on Patentability issued in International Application No. PCT/JP2022/020259 on Nov. 4, 2022. cited by applicant

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS (1) This application is a continuation application of International Application No. PCT/JP2022/020259, filed May 13, 2022, the disclosure of which is incorporated herein by reference in its entirety. Further, this application claims priority from Japanese Patent Application No. 2021-161787, filed Sep. 30, 2021, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND

Technical Field

(1) The technology of the present disclosure relates to an estimation apparatus, an imaging apparatus, a moving object, an estimation system, an estimation method, and a non-transitory storage medium storing a program.

Related Art

(2) JP2019-095963A discloses a position control system of a moving object, the position control system comprising a moving object that is remotely controllable or automatically controllable and that includes a plurality of light emitters that emit light having different wavelengths, and a ground object that is installed on a ground, in which the ground object includes a light receiving section that images the plurality of light emitters, a processing section that obtains two-dimensional coordinates of the plurality of light emitters on a two-dimensional captured image captured by the light receiving section and that obtains three-dimensional coordinates of the moving object based on the obtained two-dimensional coordinates of the plurality of light emitters, and a control unit that controls the moving object to move such that the three-dimensional coordinates obtained by the processing section match three-dimensional coordinates of a target set in advance.

(3) JP2000-055657A discloses a positioning device that identifies a plurality of moving objects moving on a floor in a room and that measures two-dimensional positions of the respective moving objects, the positioning device comprising a base station, a transmission means, and an imaging camera, the base station transmitting an identification signal corresponding to a specific moving object to all the moving objects via the transmission means, the transmission means being provided together with a light source in each moving object and receiving the identification signal to determine whether or not the identification signal corresponds to an identification signal thereof and causing the light source to emit light in a case where the identification signal corresponds to the identification signal of the reception means, the imaging camera imaging the light source of the moving object that emits light to transmit the image to the base station, in which the base station matches a position of the image to a two-dimensional position of the floor to measure a position of the moving object.

(4) JP2019-144183A discloses a three-dimensional coordinate measuring device comprising six or more reflection markers that are arranged on a surface of an object placed in an environment of natural light and that reflect one monochromatic light included in the natural light, a light source that irradiates the object with the monochromatic light, a filter of which a transmittance of a wavelength of the monochromatic light is lower than a transmittance of the other monochromatic light included in the natural light, a camera that captures three or more images of the object from different positions through the filter, and a three-dimensional coordinate extraction unit that executes photogrammetry on positions of the reflection markers in the three or more images, executes SfM using a result of the photogrammetry and feature points in the images excluding the

reflection markers, and extracts three-dimensional coordinates of the object.

SUMMARY

(5) One embodiment according to the technology of the present disclosure provides an estimation apparatus, an imaging apparatus, a moving object, an estimation system, an estimation method, and a non-transitory storage medium storing a program capable of estimating at least one of a position or a posture of the moving object even in an environment where it is difficult to use a GNSS.

(6) A first aspect according to the technology of the present disclosure is an estimation apparatus comprising a processor, in which the processor is configured to acquire positional information of a plurality of reference stations each having a light emitter that emits light in wavelength bands different from each other, acquire image data obtained by imaging an imaging scene including the light emitter via an imaging apparatus mounted on a moving object, and estimate at least one of a position of the moving object or a posture of the moving object based on an in-image position, which is a position of the light emitter in an image indicated by the image data, and the positional information of the plurality of reference stations.

(7) A second aspect according to the technology of the present disclosure is the estimation apparatus according to the first aspect, in which the image data includes a plurality of image data groups obtained by imaging the imaging scene via the imaging apparatus in a plurality of the wavelength bands, and the processor is configured to specify the in-image position of a light emitter of one reference station among the plurality of reference stations, based on a result of subtraction processing of first image data obtained by imaging the imaging scene in a light emitter wavelength band, which is a wavelength band in which the light emitter of the one reference station emits light, and second image data obtained by imaging in a first adjacent wavelength band, which has a central wavelength on one of a long wavelength side or a short wavelength side by a designated wavelength from a central wavelength of the light emitter wavelength band.

(8) A third aspect according to the technology of the present disclosure is the estimation apparatus according to the second aspect, in which the processor is configured to specify the in-image position of the light emitter of the one reference station, based on a result of subtraction processing of the first image data and third image data obtained by imaging in a second adjacent wavelength band, which has a central wavelength on another side with respect to the first adjacent wavelength band by a designated wavelength from the central wavelength of the light emitter wavelength band.

(9) A fourth aspect according to the technology of the present disclosure is the estimation apparatus according to the first aspect, in which the image data includes a plurality of image data groups obtained by imaging the imaging scene via the imaging apparatus in a plurality of the wavelength bands, and the processor is configured to specify the in-image position of a light emitter of one reference station among the plurality of reference stations, based on a result of subtraction processing of first image data obtained by imaging in a light emitter wavelength band, which is a wavelength band in which the light emitter of the one reference station emits light, and fourth image data obtained by imaging in a third adjacent wavelength band, which has a wavelength having the highest intensity on one of a long wavelength side or a short wavelength side by a designated wavelength from a wavelength having the highest intensity in the light emitter wavelength band.

(10) A fifth aspect according to the technology of the present disclosure is the estimation apparatus according to the fourth aspect, in which the processor is configured to specify the in-image position of the light emitter of the one reference station, based on a result of subtraction processing of the first image data and fifth image data obtained by imaging in a fourth adjacent wavelength band, which has a wavelength having the highest intensity on another side with respect to the third adjacent wavelength band by a designated wavelength from the wavelength having the highest intensity in the light emitter wavelength band.

(11) A sixth aspect according to the technology of the present disclosure is the estimation apparatus according to any one of the first to fifth aspects, in which the image data includes a plurality of

image data groups obtained by imaging the imaging scene via the imaging apparatus in a plurality of the wavelength bands, and the processor is configured to specify the in-image position of a light emitter of one reference station among the plurality of reference stations, based on sixth image data obtained by imaging in a wavelength band different from a light emitter wavelength band in which the light emitter of the one reference station emits light.

(12) A seventh aspect according to the technology of the present disclosure is the estimation apparatus according to any one of the first to sixth aspects, in which the positional information is obtained by converting a latitude and a longitude of each of the plurality of reference stations into coordinates in a two-dimensional orthogonal coordinate system.

(13) An eighth aspect according to the technology of the present disclosure is the estimation apparatus according to any one of the first to sixth aspects, in which the positional information is obtained by converting a latitude, a longitude, and an altitude of each of the plurality of reference stations into coordinates in a three-dimensional orthogonal coordinate system.

(14) A ninth aspect according to the technology of the present disclosure is the estimation apparatus according to any one of the first to eighth aspects, in which the plurality of reference stations are three or more.

(15) A tenth aspect according to the technology of the present disclosure is an imaging apparatus comprising an image sensor, and the estimation apparatus according to any one of the first to ninth aspects, in which the estimation apparatus is configured to estimate at least one of the position of the moving object or the posture of the moving object using an image obtained by imaging the imaging scene via the image sensor.

(16) An eleventh aspect according to the technology of the present disclosure is the imaging apparatus according to the tenth aspect, in which the image sensor is an image sensor capable of imaging in a multispectral method.

(17) A twelfth aspect according to the technology of the present disclosure is a moving object comprising an imaging apparatus, and an estimation apparatus, in which the estimation apparatus is configured to acquire positional information of a plurality of reference stations each having a light emitter that emits light in wavelength bands different from each other, acquire image data obtained by imaging an imaging scene including the light emitter via the imaging apparatus, and estimate at least one of a position of the moving object or a posture of the moving object based on an in-image position, which is a position of the light emitter in an image indicated by the image data, and the positional information of the plurality of reference stations.

(18) A thirteenth aspect according to the technology of the present disclosure is an estimation system comprising a moving object on which an imaging apparatus is mounted, an estimation apparatus, and a plurality of reference stations each having a light emitter that emits light in wavelength bands different from each other, in which the estimation apparatus is configured to acquire positional information of the plurality of reference stations, acquire image data obtained by imaging an imaging scene including the light emitter via the imaging apparatus, and estimate at least one of a position of the moving object or a posture of the moving object based on an in-image position, which is a position of the light emitter in an image indicated by the image data, and the positional information of the plurality of reference stations.

(19) A fourteenth aspect according to the technology of the present disclosure is an estimation method comprising acquiring positional information of a plurality of reference stations each having a light emitter that emits light in wavelength bands different from each other, acquiring image data obtained by imaging an imaging scene including the light emitter via an imaging apparatus mounted on a moving object, and estimating at least one of a position of the moving object or a posture of the moving object based on an in-image position, which is a position of the light emitter in an image indicated by the image data, and the positional information of the plurality of reference stations.

(20) A fifteenth aspect according to the technology of the present disclosure is a non-transitory

storage medium storing a program causing a computer to execute a process comprising acquiring positional information of a plurality of reference stations each having a light emitter that emits light in wavelength bands different from each other, acquiring image data obtained by imaging an imaging scene including the light emitter via an imaging apparatus mounted on a moving object, and estimating at least one of a position of the moving object or a posture of the moving object based on an in-image position, which is a position of the light emitter in an image indicated by the image data, and the positional information of the plurality of reference stations.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

- (1) FIG. 1 is a conceptual diagram showing an example of a use state of a moving object.
- (2) FIG. 2 is a block diagram showing an example of a hardware configuration of the moving object.
- (3) FIG. 3 is a schematic configuration diagram showing an example of a configuration of an optical system of an imaging apparatus.
- (4) FIG. 4 is a schematic configuration diagram showing an example of a configuration of an image sensor.
- (5) FIG. 5 is a block diagram showing an example of functions of main units of a processor.
- (6) FIG. 6 is a conceptual diagram showing an example of processing contents of an image processing unit.
- (7) FIG. 7 is a conceptual diagram showing an example of the processing contents of the image processing unit.
- (8) FIG. 8 is a conceptual diagram showing an example of processing contents of an estimation unit.
- (9) FIG. 9 is a conceptual diagram showing an example of estimation of a position and a posture of the moving object.
- (10) FIG. 10 is a flowchart showing an example of a flow of estimation processing.
- (11) FIG. 11 is a flowchart showing an example of a flow of light emitter specifying processing.
- (12) FIG. 12 is a block diagram showing an example of a hardware configuration of an estimation system.
- (13) FIG. 13 is a conceptual diagram showing an example of a form of installing an estimation processing program on a computer from a storage medium.

DETAILED DESCRIPTION

(14) Hereinafter, an example of an embodiment of an estimation apparatus, an imaging apparatus, a moving object, an estimation system, an estimation method, and a program according to the technology of the present disclosure will be described with reference to the accompanying drawings.

(15) First, the wording used in the following description will be described.

(16) CPU is an abbreviation for “central processing unit”. GPU is an abbreviation for “graphics processing unit”. RAM is an abbreviation for “random access memory”. EEPROM is an abbreviation for “electrically erasable programmable read-only memory”. IC is an abbreviation for “integrated circuit”. ASIC is an abbreviation for “application specific integrated circuit”. PLD is an abbreviation for “programmable logic device”. FPGA is an abbreviation for “field-programmable gate array”. SoC is an abbreviation for “system-on-a-chip”. SSD is an abbreviation for “solid state drive”. USB is an abbreviation for “universal serial bus”. HDD is an abbreviation for “hard disk drive”. EL is an abbreviation for “electro-luminescence”. I/F is an abbreviation for “interface”. UI is an abbreviation for “user interface”. GUI is an abbreviation for “graphical user interface”. CMOS is an abbreviation for “complementary metal oxide semiconductor”. CCD is an

abbreviation for “charge coupled device”. GNSS is an abbreviation for “global navigation satellite system”. LED is an abbreviation for “light emitting diode”.

First Embodiment

(17) A moving object **10** is used for surveying and/or inspecting land and/or infrastructure, or the like. Examples of the infrastructure include road facilities (for example, a bridge, a road surface, a tunnel, a guardrail, a traffic light, and/or a windbreak fence), waterway facilities, airport facilities, port facilities, water storage facilities, gas facilities, power supply facilities, medical facilities, and/or firefighting facilities. As shown in FIG. 1 as an example, the moving object **10** is an unmanned aerial vehicle (for example, a drone) that flies in a tunnel **1**.

(18) As shown in FIG. 1 as an example, the moving object **10** comprises a main body **32** and a plurality of propellers **34** (four propellers in the example shown in FIG. 1). The moving object **10** flies or hovers in a three-dimensional space by controlling a rotation of each of the plurality of propellers **34**. Further, an imaging apparatus **30** is mounted on the moving object **10**. The moving object **10** is an example of a “moving object” according to the technology of the present disclosure, and the imaging apparatus **30** is an example of an “imaging apparatus” according to the technology of the present disclosure.

(19) Here, the unmanned aerial vehicle is described as an example of the moving object **10**, but the technology of the present disclosure is not limited to this. For example, the moving object **10** may be a vehicle. Examples of the vehicle include a vehicle with a gondola, an aerial work vehicle, and a bridge inspection vehicle. In addition, the moving object **10** may be a slider, a carriage, or the like on which the imaging apparatus **30** can be mounted. In addition, the moving object **10** may be a person. Here, the person refers to, for example, a worker who performs survey and/or inspection for land and/or infrastructure, or the like. In a case where the moving object **10** is a person, the phrase “the imaging apparatus **30** is mounted” includes an aspect in which the imaging apparatus **30** is gripped by the person and/or the imaging apparatus **30** is attached to equipment (for example, a helmet, work clothes, or the like) worn by the person. In addition, the moving object **10** may be a ship or an underwater drone.

(20) Meanwhile, in a case where inspection or the like is performed on infrastructure or the like using the moving object **10**, it is required to grasp a position and a posture of the moving object **10** to control a movement of the moving object **10**. It is known that GNSS is used to grasp the position and the posture of the moving object **10**. However, as shown in FIG. 1 as an example, in a case in which the moving object **10** is placed in a shielded environment such as the inside of the tunnel **1**, communication between a satellite used in the GNSS and the moving object **10** is interrupted, and thus it is difficult to estimate the position and the posture of the moving object **10**.

(21) Therefore, in the present embodiment, to realize estimation of the position and the posture of the moving object **10** even in an environment where communication with an outside (for example, a satellite) is difficult, as shown in FIG. 1 as an example, the position and the posture of the moving object **10** are estimated by imaging a light emitter **37** of a reference station **36** via the imaging apparatus **30**.

(22) The reference station **36** is used for estimating the position and the posture of the moving object **10**. The reference station **36** is provided at a position where the light emitter **37** can be imaged by the imaging apparatus **30** of the moving object **10**. In the example shown in FIG. 1, the reference station **36** is installed around an entrance and an exit of the tunnel **1**. Three or more reference stations **36** are installed. In the example shown in FIG. 1, three reference stations **36** are installed. In the example shown in FIG. 1, the three reference stations **36** are a first reference station **36A**, a second reference station **36B**, and a third reference station **36C**.

(23) Here, although the three reference stations **36** are exemplified, this is merely an example, and four reference stations **36** may be installed around the moving object **10**, and the technology of the present disclosure is established as long as three or more reference stations **36** are installed around the moving object **10**.

(24) The light emitter **37** is provided in the reference station **36**. The light emitter **37** emits light in a predetermined wavelength band. The light emitter **37** is, for example, an LED light source. The light emitter **37** provided in each of the three reference stations **36** emits light in wavelength bands different from each other between the reference stations **36**. For example, each of the three reference stations **36** includes a blue LED light source, a yellow LED light source, and a red LED light source as the light emitter **37**.

(25) Although an example in which the LED light source is used as the light emitter **37** has been described, this is merely an example. The light emitter **37** may be a light source that can emit light in a predetermined wavelength band, and for example, an electroluminescent light source or a fluorescent lamp may be used as the light emitter **37**.

(26) In the example shown in FIG. **1**, the first reference station **36A** is provided with a first light emitter **37A**. In addition, the second reference station **36B** is provided with a second light emitter **37B**. Further, the third reference station **36C** is provided with a third light emitter **37C**. The first light emitter **37A** is a blue LED light source, the second light emitter **37B** is a yellow LED light source, and the third light emitter **37C** is a red LED light source.

(27) As shown in FIG. **2** as an example, the moving object **10** comprises the imaging apparatus **30**, a controller **17**, and an estimation apparatus **38**. The controller **17** is realized by, for example, an IC chip. A plurality of motors **17A** are provided in the main body **32**. The plurality of motors **17A** are connected to the plurality of propellers **34**. The controller **17** controls the flight of the moving object **10** by controlling the plurality of motors **17A**.

(28) The estimation apparatus **38** comprises a computer **39** and an external I/F **46**. The computer **39** comprises a processor **40**, a storage **42**, and a RAM **44**. The processor **40**, the storage **42**, the RAM **44**, and the external I/F **46** are connected to a bus **48**. The estimation apparatus **38** is an example of an “estimation apparatus” according to the technology of the present disclosure. In addition, the computer **39** is an example of a “computer” according to the technology of the present disclosure. Moreover, the processor **40** is an example of a “processor” according to the technology of the present disclosure.

(29) For example, the processor **40** has a CPU and a GPU and controls the entire estimation apparatus **38**. The GPU operates under the control of the CPU, and is responsible for executing screen display and/or image processing. In addition, the processor **40** may be one or more CPUs with which the functions of the GPU have been integrated or may be one or more CPUs with which the functions of the GPU have not been integrated.

(30) The storage **42** is a nonvolatile storage device that stores various programs, various parameters, and the like. An example of the storage **42** is a flash memory (for example, an EEPROM and/or an SSD) and/or an HDD. The flash memory and/or the HDD are merely examples, and a nonvolatile storage device such as a magnetic resistance memory, and/or a ferroelectric memory may be used instead of the HDD and/or the flash memory or together with the HDD and/or the flash memory. The RAM **44** is a memory in which information is temporarily stored and is used as a work memory by the processor **40**.

(31) The imaging apparatus **30** images an imaging scene around the moving object **10**. The imaging scene includes the light emitters **37A**, **37B**, and **37C** (see FIG. **1**). The imaging apparatus **30** is a so-called multispectral camera, and includes an imaging optical system **11** and an image sensor **20**.

(32) The imaging optical system **11** includes a fisheye lens **11A** as an objective lens. By using the fisheye lens **11A**, it is possible to image surroundings of the moving object **10** over a wide range. In addition, the image sensor **20** is an image sensor capable of imaging in a multispectral method.

(33) In addition, the imaging optical system **11** comprises a lens **12** and a pupil division filter **14**. The lens **12** causes an optical image of a subject including the target object to be formed on a light-receiving surface **20A** of the image sensor **20**. The pupil division filter **14** is comprised at or in a vicinity of a pupil position of the imaging optical system **11** and divides the pupil portion of the imaging optical system **11** into nine optical regions. As shown in FIG. **3** as an example, the pupil

division filter **14** is a filter in which a narrowband filter **16** and a polarization filter **18** are superimposed. The pupil division filter **14** has nine optical regions S_j (j =natural number from 1 to 9) equally divided into nine parts in a circumferential direction. The optical regions S_j transmit light in different wavelength bands. In addition, among the nine optical regions S_j , an optical region group including optical regions **S1** to **S3**, an optical region group including optical regions **S4** to **S6**, and an optical region group including optical regions **S7** to **S9** transmit light in polarization directions different from each other (that is, transmitted polarization azimuths). The nine optical regions S_j are realized by a combination of, for example, the narrowband filter **16** and the polarization filter **18**.

(34) The narrowband filter **16** includes nine narrowband filter units **F1** to **F9** equally divided into nine parts in the circumferential direction. The narrowband filter units **F1** to **F9** correspond to the optical regions **S1** to **S9** of the pupil division filter **14**, respectively. Each of the narrowband filter units **F1** to **F9** includes a bandpass filter that allows transmission of light of different narrowbands.

(35) That is, a first narrowband filter unit **F1** transmits light in a first wavelength band $\Delta f1$. A second narrowband filter unit **F2** transmits light in a second wavelength band $\Delta f2$. A third narrowband filter unit **F3** transmits light in a third wavelength band $\Delta f3$. A fourth narrowband filter unit **F4** transmits light in a fourth wavelength band $\Delta f4$. A fifth narrowband filter unit **F5** transmits light in a fifth wavelength band $\Delta f5$. A sixth narrowband filter unit **F6** transmits light in a sixth wavelength band $\Delta f6$. A seventh narrowband filter unit **F7** transmits light in a seventh wavelength band $\Delta f7$. An eighth narrowband filter unit **F8** transmits light in an eighth wavelength band $\Delta f8$. A ninth narrowband filter unit **F9** transmits light in a ninth wavelength band $\Delta f9$.

(36) The second wavelength band $\Delta f2$ is a wavelength band corresponding to a wavelength band of a blue LED light source. A central wavelength of the second wavelength band $\Delta f2$ matches a central wavelength of the blue LED light source (that is, 503 nm, and hereinafter, also simply referred to as “blue central wavelength”). In addition, a band width of the second wavelength band $\Delta f2$ is preferably within a band width of the wavelength band of the blue LED light source. In the present embodiment, the term “match” means match including an error that is generally allowed in the technical field to which the technology of the present disclosure belongs and that does not deviate from the gist of the technology of the present disclosure, in addition to perfect match.

(37) That is, the central wavelength of the second wavelength band $\Delta f2$ does not need to completely match the blue central wavelength, and may be at least in a range of less than a half-width of a light emission spectrum of the blue LED light source from the blue central wavelength. The second wavelength band $\Delta f2$ is an example of a “light emitter wavelength band” according to the technology of the present disclosure.

(38) The first wavelength band $\Delta f1$ has a central wavelength on a short wavelength side by a designated wavelength from the central wavelength of the second wavelength band $\Delta f2$ (that is, the blue central wavelength). For example, the central wavelength of the first wavelength band $\Delta f1$ is $503\text{ nm}-\lambda_1$, which is shorter than the central wavelength of the second wavelength band $\Delta f2$ by λ_1 (see FIG. 6). In addition, the third wavelength band $\Delta f3$ has a central wavelength on a long wavelength side by a designated wavelength from the central wavelength of the second wavelength band $\Delta f2$ (that is, the blue central wavelength). The central wavelength of the third wavelength band $\Delta f3$ is $503\text{ nm}+\lambda_3$, which is longer than the central wavelength of the second wavelength band $\Delta f2$ by λ_3 (see FIG. 6). That is, unlike the first wavelength band $\Delta f1$ and the second wavelength band $\Delta f2$, the third wavelength band $\Delta f3$ is a wavelength band on an opposite side to the first wavelength band $\Delta f1$ with the second wavelength band $\Delta f2$ interposed therebetween in a light emission spectrum. The first wavelength band $\Delta f1$ is an example of a “first adjacent wavelength band” according to the technology of the present disclosure, and the third wavelength band $\Delta f3$ is an example of a “second adjacent wavelength band” according to the technology of the present disclosure.

(39) In addition, it is preferable that each of λ_1 and λ_3 is a value separated by more than or equal to

the half-width of the light emission spectrum of the blue LED light source from the central wavelength of the second wavelength band Δf_2 .

(40) The fifth wavelength band Δf_5 is a wavelength band corresponding to a wavelength band of a yellow LED light source. A central wavelength of the fifth wavelength band Δf_5 matches a central wavelength of the yellow LED light source (that is, 592 nm, and hereinafter, also simply referred to as “yellow central wavelength”). A band width of the fifth wavelength band Δf_5 is preferably within a band width of the wavelength band of the yellow LED light source.

(41) The fourth wavelength band Δf_4 and the sixth wavelength band Δf_6 are wavelength bands on a short wavelength side and a long wavelength side, respectively, with the fifth wavelength band Δf_5 interposed therebetween. A central wavelength of the fourth wavelength band Δf_4 is $592 \text{ nm} - \lambda_4$, and a central wavelength of the sixth wavelength band Δf_6 is $592 \text{ nm} + \lambda_6$ (see FIG. 6). It is preferable that each of λ_4 and λ_6 is a value separated by more than or equal to the half-width of the light emission spectrum of the yellow LED light source from the central wavelength of the fifth wavelength band Δf_5 .

(42) The eighth wavelength band Δf_8 is a wavelength band corresponding to a wavelength band of a red LED light source. A central wavelength of the eighth wavelength band Δf_8 matches a central wavelength of the red LED light source (that is, 630 nm, and hereinafter, also simply referred to as “red central wavelength”). A band width of the eighth wavelength band Δf_8 is preferably within a band width of the wavelength band of the red LED light source.

(43) The seventh wavelength band Δf_7 and the ninth wavelength band Δf_9 are wavelength bands on a short wavelength side and a long wavelength side, respectively, with the eighth wavelength band Δf_8 interposed therebetween. A central wavelength of the seventh wavelength band Δf_7 is $630 \text{ nm} - \lambda_7$, and a central wavelength of the ninth wavelength band Δf_9 is $630 \text{ nm} + \lambda_9$ (see FIG. 6). It is preferable that each of λ_7 and λ_9 is a value separated by more than or equal to the half-width of the light emission spectrum of the red LED light source from the central wavelength of the eighth wavelength band Δf_8 .

(44) The polarization filter **18** has three polarization filter units G1 to G3 equally divided into three parts in the circumferential direction. A first polarization filter unit G1 corresponds to a first optical region S1 to a third optical region S3 of the pupil division filter **14**. A second polarization filter unit G2 corresponds to a fourth optical region S4 to a sixth optical region S6 of the pupil division filter **14**. A third polarization filter unit G3 corresponds to a seventh optical region S7 to a ninth optical region S9 of the pupil division filter **14**.

(45) The polarization filter units G1 to G3 transmit light in different polarization directions (that is, transmitted polarization azimuths). Here, a polarization direction of light transmitted by the first polarization filter unit G1 is denoted by α_1 . A polarization direction of light transmitted by the second polarization filter unit G2 is denoted by α_2 . A polarization direction of light transmitted by the third polarization filter unit G3 is denoted by α_3 . In the imaging apparatus **30**, the first polarization filter unit G1 transmits light having an azimuthal angle of 0° (that is, $\alpha_1 = 0^\circ$). The second polarization filter unit G2 transmits light having an azimuthal angle of 60° (that is, $\alpha_2 = 60^\circ$). The third polarization filter unit G3 transmits light having an azimuthal angle of 120° (that is, $\alpha_3 = 120^\circ$).

(46) The pupil division filter **14** obtained by superimposing the narrowband filter **16** and the polarization filter **18** described above on the same axis acts as follows.

(47) Light that passes through the first optical region S1 of the pupil division filter **14** passes through the first narrowband filter unit F1 of the narrowband filter **16** and the first polarization filter unit G1 of the polarization filter **18**. Thus, light of the first wavelength band Δf_1 is subjected to linear polarization in a polarization direction α_1 and exits from the first optical region S1. Light that passes through the second optical region S2 of the pupil division filter **14** passes through the second narrowband filter unit F2 of the narrowband filter **16** and the first polarization filter unit G1 of the polarization filter **18**. Thus, light of the second wavelength band Δf_2 is subjected to linear

polarization in the polarization direction α_1 and exits from the second optical region S2. Light that passes through the third optical region S3 of the pupil division filter **14** passes through the third narrowband filter unit F3 of the narrowband filter **16** and the first polarization filter unit G1 of the polarization filter **18**. Thus, light of the third wavelength band Δf_3 is subjected to linear polarization in the polarization direction α_1 and exits from the third optical region S3.

(48) In addition, light that passes through the fourth optical region S4 of the pupil division filter **14** passes through the fourth narrowband filter unit F4 of the narrowband filter **16** and the second polarization filter unit G2 of the polarization filter **18**. Thus, light of the fourth wavelength band Δf_4 is subjected to linear polarization in a polarization direction α_2 and exits from the fourth optical region S4. Light that passes through the fifth optical region S5 of the pupil division filter **14** passes through the fifth narrowband filter unit F5 of the narrowband filter **16** and the second polarization filter unit G2 of the polarization filter **18**. Thus, light of the fifth wavelength band Δf_5 is subjected to linear polarization in the polarization direction α_2 and exits from the fifth optical region S5. Light that passes through the sixth optical region S6 of the pupil division filter **14** passes through the sixth narrowband filter unit F6 of the narrowband filter **16** and the second polarization filter unit G2 of the polarization filter **18**. Thus, light of the sixth wavelength band Δf_6 is subjected to linear polarization in the polarization direction α_2 and exits from the sixth optical region S6.

(49) In addition, light that passes through the seventh optical region S7 of the pupil division filter **14** passes through the seventh narrowband filter unit F7 of the narrowband filter **16** and the third polarization filter unit G3 of the polarization filter **18**. Thus, light of the seventh wavelength band Δf_7 is subjected to linear polarization in a polarization direction α_3 and exits from the seventh optical region S7. Light that passes through the eighth optical region S8 of the pupil division filter **14** passes through the eighth narrowband filter unit F8 of the narrowband filter **16** and the third polarization filter unit G3 of the polarization filter **18**. Thus, light of the eighth wavelength band Δf_8 is subjected to linear polarization in the polarization direction α_3 and exits from the eighth optical region S8. Light that passes through the ninth optical region S9 of the pupil division filter **14** passes through the ninth narrowband filter unit F9 of the narrowband filter **16** and the third polarization filter unit G3 of the polarization filter **18**. Thus, light of the ninth wavelength band Δf_9 is subjected to linear polarization in the polarization direction α_3 and exits from the ninth optical region S9.

(50) The entire imaging optical system **11** is disposed to be movable forward and rearward along the optical axis L. Therefore, focus is adjusted.

(51) As shown in FIG. 4 as an example, the image sensor **20** includes a plurality of pixels P_i (i =natural number from 1 to 9) on the light-receiving surface **20A**. The pixels P_i are regularly arranged at a regular pitch along a horizontal direction (that is, an x direction shown in FIG. 4) and a vertical direction (that is, a y direction shown in FIG. 4).

(52) The image sensor **20** has a pixel block PB including nine (that is, three×three) adjacent pixels P_i . Hereinafter, for convenience of description, in a case of describing any pixel block PB, the pixel block PB will be referred to as PB(x, y). The notation of (x, y) indicates that a certain pixel block PB is arranged at an xth position in the horizontal direction (that is, the x direction shown in FIG. 4) and at a yth position in the vertical direction (that is, the y direction shown in FIG. 4).

(53) The pixel block PB(x, y) is regularly arranged along the horizontal direction (that is, the x direction shown in FIG. 4) and the vertical direction (that is, the y direction shown in FIG. 4). The pixels P_i receive light having different characteristics.

(54) The image sensor **20** has a pixel array layer **21**, a polarization filter element array layer **23**, a spectroscopic filter element array layer **25**, and a microlens array layer **27**. Each layer is arranged in an order of the pixel array layer **21**, the polarization filter element array layer **23**, the spectroscopic filter element array layer **25**, and the microlens array layer **27** from an image plane side to an object side.

(55) The pixel array layer **21** has multiple photodiodes **22** arranged two-dimensionally. One

photodiode **22** corresponds to one pixel. Each photodiode **22** is regularly arranged along the horizontal direction (that is, the x direction shown in FIG. **4**) and the vertical direction (that is, the y direction shown in FIG. **4**).

(56) The polarization filter element array layer **23** has three types of polarization filter elements **24A**, **24B**, and **24C** having polarization directions (that is, transmitted polarization azimuths) different from each other. The polarization filter elements **24A**, **24B**, and **24C** are two-dimensionally arranged. Each of the polarization filter elements **24A**, **24B**, and **24C** is arranged at the same intervals as the pixel array layer **21**. In addition, each of the polarization filter elements **24A**, **24B**, and **24C** is comprised for each pixel. It is assumed that a polarization direction of light transmitted by a first polarization filter element **24A** is β_1 , a polarization direction of light transmitted by a second polarization filter element **24B** is β_2 , and a polarization direction of light transmitted by a third polarization filter element **24C** is β_3 .

(57) The first polarization filter element **24A** transmits light having an azimuthal angle of 0° (that is, $\beta_1=0^\circ$). The second polarization filter element **24B** transmits light having an azimuthal angle of 60° (that is, $\beta_2=60^\circ$). The third polarization filter element **24C** transmits light having an azimuthal angle of 120° (that is, $\beta_3=120^\circ$).

(58) In each pixel block PB(x, y), the polarization filter elements **24A**, **24B**, and **24C** are regularly arranged. The first polarization filter element **24A** is arranged in a first pixel P1, a fourth pixel P4, and a seventh pixel P7, which are pixels in the first column in the pixel block PB(x,y). The second polarization filter element **24B** is arranged in a second pixel P2, a fifth pixel P5, and an eighth pixel P8, which are pixels in the second column in the pixel block PB(x,y). The third polarization filter element **24C** is arranged in a third pixel P3, a sixth pixel P6, and a ninth pixel P9, which are pixels in the third column in the pixel block PB(x,y).

(59) The spectroscopic filter element array layer **25** has three types of spectroscopic filter elements **26A**, **26B**, and **26C** having spectroscopic transmittances different from each other. The spectroscopic filter elements **26A**, **26B**, and **26C** are two-dimensionally arranged. The spectroscopic filter elements **26A**, **26B**, and **26C** are arranged at the same interval as the photodiodes **22**, and are arranged in each pixel.

(60) The spectroscopic filter elements **26A**, **26B**, and **26C** allow transmission of light transmitted through each of the narrowband filter units F1 to F9 of the narrowband filter **16** with different transmittances. A first spectroscopic filter element **26A** has a characteristic of transmitting a larger amount of light in a short wavelength band of a wavelength band of visible light. A second spectroscopic filter element **26B** has a characteristic of transmitting a larger amount of light in an intermediate wavelength band. A third spectroscopic filter element **26C** has a characteristic of transmitting a larger amount of light in a long wavelength band. For example, the spectroscopic filter elements **26A**, **26B**, and **26C** may be color filters of B, G, and R disposed in a general color image sensor.

(61) In each pixel block PB(x, y), the spectroscopic filter elements **26A**, **26B**, and **26C** are regularly arranged. The first spectroscopic filter element **26A** is arranged in the first pixel P1, the second pixel P2, and the third pixel P3, which are pixels in the first row in the pixel block PB(x,y). The second spectroscopic filter element **26B** is arranged in the fourth pixel P4, the fifth pixel P5, and the sixth pixel P6, which are pixels in the second row in the pixel block PB(x,y). The third spectroscopic filter element **26C** is arranged in the seventh pixel P7, the eighth pixel P8, and the ninth pixel P9, which are pixels in the third row in the pixel block PB(x,y).

(62) The microlens array layer **27** has a large number of microlenses **28** arranged two-dimensionally. Each of the microlenses **28** is arranged at the same interval as the photodiodes **22** and is comprised in each pixel. The microlenses **28** are arranged for a purpose of efficiently condensing light from the imaging optical system **11** on the photodiodes **22**.

(63) In the image sensor **20** described above, in each pixel block PB(x,y), each pixel Pi has different combinations of the spectroscopic filter elements **26A**, **26B**, and **26C** and the polarization

filter elements **24A**, **24B**, and **24C**. Accordingly, in the pixel **Pi** in the pixel block **PB(x,y)**, light having different characteristics is received.

(64) Meanwhile, in a case where the light emitter **37** is imaged by the imaging apparatus **30** to estimate the position and the posture of the moving object **10**, it is necessary to specify an image **50** (hereinafter, also referred to as a “light emitter image **50**”) indicating the light emitter **37** in an image obtained by imaging an imaging scene including the light emitter **37**. However, depending on imaging conditions (for example, a distance from the moving object **10** to the light emitter **37**, brightness of the periphery in a case of imaging, or the like), it may be difficult to distinguish the light emitter image **50** from a subject image other than the light emitter **37** in the image obtained by imaging the imaging scene.

(65) In view of these circumstances, in the present embodiment, for example, as shown in FIG. 5, the processor **40** of the estimation apparatus **38** performs estimation processing. An estimation processing program **42A** is stored in the storage **42**. The processor **40** reads out the estimation processing program **42A** from the storage **42** and executes the read-out estimation processing program **42A** on the RAM **44** to perform estimation processing. The estimation processing is realized by the processor **40** operating as an acquisition unit **40A**, an image processing unit **40B**, and an estimation unit **40C**. The estimation processing program **42A** is an example of a “program” according to the technology of the present disclosure.

(66) The acquisition unit **40A** acquires positional information of the reference station **36** from the storage **42**. The storage **42** stores positional information acquired via the external I/F **46** in advance. The positional information of the reference station **36** is obtained, for example, by converting a longitude, a latitude, and an altitude, which are GNSS coordinates of the reference station **36**, into coordinates of a three-dimensional orthogonal coordinate system. Here, a use of the coordinates converted into the three-dimensional orthogonal coordinate system as the positional information of the reference station **36** is merely an example. For example, the GNSS coordinates of the reference station **36** may be used as positional information as they are.

(67) The acquisition unit **40A** acquires image data from the imaging apparatus **30**. The image data is data indicating an image in which the imaging scene is included as an image. The image data is obtained by imaging the imaging scene via the imaging apparatus **30**. The image data includes a plurality of image data groups indicating images obtained by imaging an imaging scene around the moving object **10** in a plurality of the wavelength bands. That is, the image data includes the plurality of image data groups obtained by imaging the imaging scene in each of the first wavelength band $\Delta f1$, the second wavelength band $\Delta f2$, the third wavelength band $\Delta f3$, the fourth wavelength band $\Delta f4$, the fifth wavelength band $\Delta f5$, the sixth wavelength band $\Delta f6$, the seventh wavelength band $\Delta f7$, the eighth wavelength band $\Delta f8$, and the ninth wavelength band $\Delta f9$.

(68) The image processing unit **40B** performs image processing for specifying the light emitter **37** included as an image in the image indicated by the image data acquired by the acquisition unit **40A**. First, a case where the light emitter image **50A** indicating the first light emitter **37A**, which is a blue LED light source, is specified in the image will be described as an example.

(69) As shown in FIG. 6 as an example, first, the image processing unit **40B** extracts a determination region including the light emitter image **50**, based on six pieces of image data of the fourth wavelength band $\Delta f4$ to the ninth wavelength band $\Delta f9$. The six pieces of image data of the fourth wavelength band $\Delta f4$ to the ninth wavelength band $\Delta f9$ are image data not including the blue light emission spectrum emitted from the first light emitter **37A** among nine pieces of image data of the first wavelength band $\Delta f1$ to the ninth wavelength band $\Delta f9$. In the present embodiment, the concept of “not including” also includes concept of “not including” in a sense including an error generally allowed in the technical field to which the technology of the present disclosure belongs, which is the error to the extent that it does not contradict the purpose of the technology of the present disclosure, in addition to the concept of exactly “not including”.

(70) The image processing unit **40B** performs non-determination region determination processing

of determining a region in which the light emitter image 50A is not present as a non-determination region, based on the six pieces of image data of the fourth wavelength band $\Delta f4$ to the ninth wavelength band $\Delta f9$. The fourth wavelength band $\Delta f4$ to the ninth wavelength band $\Delta f9$ are examples of a “wavelength band different from the light emitter wavelength band” according to the technology of the present disclosure. The six pieces of image data of the fourth wavelength band $\Delta f4$ to the ninth wavelength band $\Delta f9$ are examples of “sixth image data” according to the technology of the present disclosure.

(71) For example, for a certain pixel P_i , six pieces of pixel data (that is, pixel values) of a position corresponding to the pixel P_i are obtained from the six pieces of image data of the fourth wavelength band $\Delta f4$ to the ninth wavelength band $\Delta f9$ that do not include a light emission spectrum of the first light emitter 37A among the nine pieces of image data. In a case where even one of the obtained six pieces of pixel data exceeds a threshold value, the position corresponding to the pixel P_i is determined as a region in which the light emitter image 50A is not present (hereinafter, also referred to as a “non-determination region”). The determination of the non-determination region in which the light emitter image 50A is not present is realized by determining whether or not the position corresponding to the pixel P_i is the non-determination region for all the pixel data of the image data indicating the imaging scene via the image processing unit 40B.

(72) The image processing unit 40B extracts a region obtained by excluding the non-determination region from the imaging scene as a determination region in which the light emitter image 50A may be present, based on a result of determining the non-determination region in which the light emitter image 50A is not present.

(73) The image processing unit 40B determines whether or not a target shown in the determination region is the light emitter image 50A for the extracted determination region. As shown in FIG. 7 as an example, the image processing unit 40B determines whether or not a target in the determination region is the light emitter image 50A, based on three pieces of image data of the first wavelength band $\Delta f1$ to the third wavelength band $\Delta f3$.

(74) Meanwhile, it is considered that an image indicating another light source or a reflecting object that emits blue light is present in the determination region, in addition to the light emitter image 50A. However, even in a case where the light is blue, the other light source or the reflecting object emitting blue light does not emit light of a narrowband having a central wavelength of 503 nm and a wavelength width of approximately 30 to 50 nm unlike the blue LED light source.

(75) Therefore, the image processing unit 40B subtracts the image data of the second wavelength band $\Delta f2$ in which the central wavelength matches the blue central wavelength and the image data of the first wavelength band $\Delta f1$, which has the central wavelength on the short wavelength side by the designated wavelength from the central wavelength of the second wavelength band $\Delta f2$. For example, the image processing unit 40B subtracts the image data of the first wavelength band $\Delta f1$ from the image data of the second wavelength band $\Delta f2$. The image processing unit 40B determines whether or not the target in the determination region is the light emitter image 50A based on a result of the subtraction processing. The image data of the second wavelength band $\Delta f2$ is an example of “first image data” according to the technology of the present disclosure, and the image data of the first wavelength band $\Delta f1$ is an example of “second image data” according to the technology of the present disclosure.

(76) Similarly, the image processing unit 40B subtracts the image data of the second wavelength band $\Delta f2$ in which the central wavelength matches the blue central wavelength and the image data of the third wavelength band $\Delta f3$, which has the central wavelength on the long wavelength side by the designated wavelength from the central wavelength of the second wavelength band $\Delta f2$. For example, the image processing unit 40B subtracts the image data of the third wavelength band $\Delta f3$ from the image data of the second wavelength band $\Delta f2$. The image processing unit 40B determines whether or not the target shown in the determination region is the light emitter image 50A based on a result of the subtraction processing. The image data of the third wavelength band

$\Delta f3$ is an example of “third image data” according to the technology of the present disclosure.

(77) In a case where the target in the determination region is the light emitter image **50A**, a light emission intensity in the subtraction result is not significantly reduced. On the other hand, in a case of another light source or the reflecting object that does not have a light emission spectrum such as a blue LED light source, the light emission intensity in the subtraction result becomes significantly smaller or a negative value. Therefore, the image processing unit **40B** can determine whether or not the target shown in the determination region is the light emitter image **50A** from the result of the subtraction processing.

(78) In addition, the image processing unit **40B** performs the image processing in the same manner as a case where the first light emitter **37A** is specified, even in a case where the second light emitter **37B** that is a yellow LED light source is specified. That is, first, the image processing unit **40B** extracts the determination region based on six pieces of image data of the first wavelength band $\Delta f1$ to the third wavelength band $\Delta f3$ and the seventh wavelength band $\Delta f7$ to the ninth wavelength band $\Delta f9$. Further, the image processing unit **40B** subtracts, in the extracted determination region, the image data of the fifth wavelength band $\Delta f5$ in which the central wavelength matches the yellow central wavelength and the image data of the fourth wavelength band $\Delta f4$, which has the central wavelength on the short wavelength side by the designated wavelength from the central wavelength of the fifth wavelength band $\Delta f5$. In addition, the image processing unit **40B** subtracts the image data of the fifth wavelength band $\Delta f5$ in which the central wavelength matches the yellow central wavelength and the image data of the sixth wavelength band $\Delta f6$, which has the central wavelength on the long wavelength side by the designated wavelength from the central wavelength of the fifth wavelength band $\Delta f5$. The image processing unit **40B** determines whether or not the target shown in the determination region is an image **50B** indicating the second light emitter **37B** based on a result of the subtraction processing.

(79) In addition, the image processing unit **40B** performs the image processing in the same manner as a case where the first light emitter **37A** and the second light emitter **37B** are specified, even in a case where the third light emitter **37C** that is a red LED light source is specified. That is, first, the image processing unit **40B** extracts the determination region based on six pieces of image data of the first wavelength band $\Delta f1$ to the sixth wavelength band $\Delta f6$. Further, the image processing unit **40B** subtracts, in the extracted determination region, the image data of the eighth wavelength band $\Delta f8$ in which the central wavelength matches a red central wavelength and the image data of the seventh wavelength band $\Delta f7$, which has the central wavelength on the short wavelength side by the designated wavelength from the central wavelength of the eighth wavelength band $\Delta f8$. In addition, the image processing unit **40B** subtracts the image data of the eighth wavelength band $\Delta f8$ in which the central wavelength matches the red central wavelength and the image data of the ninth wavelength band $\Delta f9$, which has the central wavelength on the long wavelength side by the designated wavelength from the central wavelength of the eighth wavelength band $\Delta f8$. The image processing unit **40B** determines whether or not the target shown in the determination region is an image **50C** indicating the third light emitter **37C** based on a result of the subtraction processing.

(80) The image processing unit **40B** specifies an in-image position GP (hereinafter, also simply referred to as an “in-image position GP”) that is a position of the light emitter image **50** in an image, based on a result of specifying the light emitter image **50**. Specifying the in-image position GP refers to calculating two-dimensional coordinates of a pixel forming the light emitter image **50** in the image indicated by the image data. In the example shown in FIG. 7, an example in which the in-image position GP of the light emitter image **50A** is specified is shown.

(81) As shown in FIG. 8 as an example, the estimation unit **40C** acquires the in-image position GP calculated by the image processing unit **40B**. In addition, the estimation unit **40C** acquires the positional information of the reference station **36** from the acquisition unit **40A**.

(82) In addition, the estimation unit **40C** estimates the position and the posture of the moving object **10** based on the positional information of the reference station **36** and the in-image position

GP. Estimating the position and the posture of the moving object **10** refers to calculating position coordinates of the moving object **10** in a three-dimensional orthogonal coordinate system in a three-dimensional space, as well as a roll angle, a pitch angle, and a yaw angle of the moving object **10**.

(83) In a case of estimating a position and a posture of an object based on the position of the object in a three-dimensional space and the position of the object in an in-image coordinate system, the position and the posture of the object can be estimated by generally solving a perspective n-point problem (PnP problem). For example, the position and the posture of the moving object **10** are estimated by using a solution described in “Nakano et al., ‘Unified Solution for PnP Problem of General Camera Model Using Gröbner Basis’, Meeting on Image Recognition and Understanding (MIRU2011), pp. 845 to 851, 2011”. The estimation unit **40C** estimates the position and the posture of the moving object **10** by using an arithmetic expression in which the in-image position GP and the positional information (for example, three-dimensional orthogonal coordinates) of the reference station **36** corresponding to the light emitter **37** are used as independent variables and the position coordinates and Euler angles of the moving object **10** in the three-dimensional orthogonal coordinate system are used as dependent variables. The method of estimating the position and the posture of the moving object **10** described here is merely an example, and various solutions to the PnP problem may be appropriately used as the method of estimating the position and the posture of the moving object **10**. Further, in estimating the posture of the moving object **10**, the posture of the moving object **10** may be estimated as the posture in a body coordinate system by converting an inertial coordinate system into the body coordinate system using a direction cosine matrix. FIG. **9** shows, as an example of the body coordinate system, a coordinate system having a centroid G of the moving object **10** as an origin and consisting of an axis X.sub.L, an axis Y.sub.L, and an axis Z.sub.L.

(84) In a case where the position and the posture of the moving object **10** are estimated, as shown in FIG. **9** as an example, the estimation apparatus **38** outputs a result of estimating the position and the posture of the moving object **10** to the controller **17**. The controller **17** controls the position and the posture of the moving object **10** based on the result of estimating the position and the posture of the moving object **10**. For example, in a case where the moving object **10** is at a position deviating from a predetermined route, the controller **17** controls an operation of the motor **17A** such that the moving object **10** returns to the predetermined route.

(85) Next, an operation of the estimation apparatus **38** will be described with reference to FIGS. **10** and **11**.

(86) In FIGS. **10** and **11**, an example of a flow of the estimation processing performed by the processor **40** is shown. It should be noted that the flow of the estimation processing shown in FIGS. **10** and **11** is an example of an “estimation method” according to the technology of the present disclosure.

(87) As an example, in the estimation processing shown in FIG. **10**, first, in step ST**10**, the acquisition unit **40A** determines whether or not an estimation timing for estimating the position and the posture of the moving object **10** is reached. Examples of the estimation timing include a condition that a predetermined time has elapsed from a time point at which a previous estimation is performed. In step ST**10**, in a case where the estimation timing is not reached, a negative determination is made, and the estimation processing transitions to step ST**10**. In step ST**10**, in a case where the estimation timing is reached, a positive determination is made, and the estimation processing transitions to step ST**12**.

(88) In step ST**12**, the acquisition unit **40A** acquires the positional information of the reference station **36** from the storage **42**. After the processing of step ST**12** is executed, the estimation processing transitions to step ST**14**.

(89) In step ST**14**, the acquisition unit **40A** causes the imaging apparatus **30** to image the imaging scene. After the processing of step ST**14** is executed, the estimation processing transitions to step

ST16.

(90) In step ST16, the acquisition unit 40A acquires the image data obtained by causing the imaging apparatus 30 to image the imaging scene in step ST14. After the processing of step ST16 is executed, the estimation processing transitions to step ST18.

(91) In step ST18, the image processing unit 40B performs the light emitter specifying processing shown in FIG. 11 as an example. In the light emitter specifying processing shown in FIG. 11, first, in step ST20, the image processing unit 40B extracts the determination region, based on the image data obtained by imaging in the wavelength band different from the wavelength band in which the light emitter 37 emits light. After the processing of step ST20 is executed, the light emitter specifying processing transitions to step ST22.

(92) In step ST22, the image processing unit 40B performs subtraction processing, in the determination region extracted in step ST20, on image data obtained by imaging in a wavelength band in which the light emitter 37 emits light and image data obtained by imaging in a wavelength band, which has a central wavelength on a short wavelength side or a long wavelength side from a central wavelength of the wavelength band in which the light emitter 37 emits light. After the processing of step ST22 is executed, the light emitter specifying processing transitions to step ST24.

(93) In step ST24, the image processing unit 40B specifies the light emitter image 50 in the image based on a subtraction result calculated in step ST22. After the processing of step ST24 is executed, the light emitter specifying processing transitions to step ST26.

(94) In step ST26, the image processing unit 40B calculates the in-image position GP based on a result of specifying the light emitter image 50 in step ST24. After the processing of step ST26 is executed, the light emitter specifying processing transitions to step ST28.

(95) In step ST28, the image processing unit 40B determines whether or not all the in-image positions GP are specified. In step ST28, in a case in which all the in-image positions GP are not specified, a negative determination is made, and the light emitter specifying processing transitions to step ST20. In step ST28, in a case in which all the in-image positions GP are specified, a positive determination is made, and the light emitter specifying processing transitions to step ST30 of the estimation processing shown in FIG. 10 as an example.

(96) In step ST30, the estimation unit 40C estimates the position and the posture of the moving object 10, based on the in-image position GP calculated by the image processing unit 40B and the positional information of the reference station 36 acquired by the acquisition unit 40A. After the processing of step ST30 is executed, the estimation processing transitions to step ST32.

(97) In step ST32, the estimation unit 40C determines whether or not a condition for ending the estimation processing (hereinafter, referred to as an “end condition”) is satisfied. An example of the end condition includes a condition that the moving object 10 ends the movement along a predetermined route. In step ST32, in a case in which the end condition is not satisfied, a negative determination is made, and the estimation processing transitions to step ST10. In step ST32, in a case in which the end condition is satisfied, a positive determination is made, and the estimation processing ends.

(98) As described above, in the moving object 10 according to the present embodiment, it is realized to estimate at least one of the position or the posture of the moving object 10 even in an environment in which the use of the GNSS is difficult.

(99) In addition, in the moving object 10, for example, in a case where the light emitter 37 is a blue LED light source, the in-image position GP is specified based on a result of subtraction processing of the image data obtained by imaging in the second wavelength band $\Delta f2$ and the image data obtained by imaging in the first wavelength band $\Delta f1$. Therefore, with the present configuration, it is realized to specify the in-image position GP more accurately and more quickly than a case in which the in-image position GP is specified by using only the image data obtained by imaging in the second wavelength band $\Delta f2$.

(100) In addition, in the moving object **10**, for example, in a case where the light emitter **37** is a blue LED light source, the in-image position GP is specified based on a result of subtraction processing of the image data obtained by imaging in the second wavelength band $\Delta f2$ and the image data obtained by imaging in the third wavelength band $\Delta f3$. Therefore, with the present configuration, it is realized to specify the in-image position GP more accurately and more quickly than a case in which the in-image position GP is specified by using only the image data obtained by imaging in the second wavelength band $\Delta f2$.

(101) In addition, in the moving object **10**, for example, in a case where the light emitter **37** is a blue LED light source, the in-image position GP is specified based on six pieces of image data of the fourth wavelength band $\Delta f4$ to the ninth wavelength band $\Delta f9$, which are wavelength bands different from the second wavelength band $\Delta f2$. Therefore, with the present configuration, it is realized to specify the in-image position GP more accurately and more quickly than a case in which the in-image position GP is specified by using only the image data obtained by imaging in the second wavelength band $\Delta f2$.

(102) In addition, in the moving object **10**, the positional information is obtained by converting a latitude, a longitude, and an altitude of each of the plurality of reference stations **36** into coordinates in a three-dimensional orthogonal coordinate system. Therefore, with the present configuration, as compared with a case in which the latitude, the longitude, and the altitude are used as they are as the positional information of the reference station **36**, a calculation required for estimating the position and the posture of the moving object **10** is facilitated, and at least one of the position or the posture of the moving object **10** can be estimated more quickly.

(103) In addition, in the moving object **10**, since the position and the posture of the moving object **10** are estimated by using three or more reference stations **36**, at least one of the position or the posture of the moving object **10** can be more accurately estimated as compared with a case where the number of the reference stations **36** is less than three.

(104) In addition, in the moving object **10**, since the imaging apparatus **30** comprises the image sensor **20** capable of imaging in a multispectral method, the in-image position GP can be specified more accurately and more quickly than a case where the image sensor **20** is not capable of imaging in a multispectral method.

Second Embodiment

(105) In the first embodiment, although the form example in which the estimation apparatus **38** is provided in the moving object **10** and the estimation processing of the position and the posture is performed in the moving object **10** has been described, the technology of the present disclosure is not limited to this. In the present second embodiment, the estimation processing is executed in an information processing apparatus **71** provided outside a moving object **10A**.

(106) As shown in FIG. **12** as an example, an estimation system **70** includes the moving object **10A**, the reference station **36**, and the information processing apparatus **71**. The estimation system **70** is an example of an “estimation system” according to the technology of the present disclosure. The information processing apparatus **71** is an example of an “estimation apparatus” according to the technology of the present disclosure. The information processing apparatus **71** is, for example, a notebook personal computer, but is merely an example, and may be a tablet terminal or a smartphone, or may be a desktop personal computer. In addition, it is not limited to a personal computer and may be a server. The server may be a mainframe used on-premises together with the moving object **10A** or may be an external server implemented by cloud computing. In addition, the server may be an external server implemented by network computing such as fog computing, edge computing, or grid computing. The information processing apparatus **71** may be a terminal for operating the moving object **10A**.

(107) The information processing apparatus **71** comprises a reception device **76** and a display **75**. The reception device **76** has a keyboard, a mouse, a touch panel, and the like, and receives an instruction from a user. The display **75** displays various types of information (for example, an

image and a character). Examples of the display 75 include an EL display (for example, an organic EL display or an inorganic EL display). It should be noted that the display is not limited to the EL display, and another type of display, such as a liquid crystal display, may be applied.

(108) The moving object 10A is wirelessly communicatively connected to the information processing apparatus 71, and various types of information are wirelessly exchanged between the moving object 10A and the information processing apparatus 71. For example, in a case where the moving object 10A is performing an inspection in the tunnel, the information processing apparatus 71 is installed within a distance in which wireless communication is possible with the moving object 10A in the tunnel being inspected by the moving object 10A. A communication I/F 77 performs wireless communication with a communication I/F 19 of the moving object 10A to receive image data from the moving object 10A. The image data received via the communication I/F 77 is acquired and processed by the processor 40.

(109) The information processing apparatus 71 acquires the positional information of the reference station 36. A method of acquiring the positional information of the reference station 36 is not particularly limited, but for example, the positional information of the reference station 36 may be acquired by exchanging information between the information processing apparatus 71 and the reference station 36 through wired or wireless communication, or may be acquired via a portable storage medium in which the positional information of the reference station 36 is stored. The positional information of the reference station 36 acquired by the information processing apparatus 71 is stored in the storage 42.

(110) The processor 40 estimates the position and the posture of the moving object 10A, based on the image data acquired via the communication I/F 77 and the positional information of the reference station 36 acquired from the storage 42. The processor 40 performs GUI control to display estimation results of the position and the posture of the moving object 10A on the display 75. In addition, the processor 40 outputs the estimation results of the position and the posture of the moving object 10A to the moving object 10A via the communication I/F 77.

(111) The communication I/F 19 of the moving object 10A performs wireless communication with the communication I/F 77 of the information processing apparatus 71 to receive the estimation results of the position and the posture of the moving object 10A. The controller 17 controls a flight of the moving object 10A based on the estimation results of the position and the posture of the moving object 10A acquired via the communication I/F 19.

(112) As described above, in the estimation system 70 according to the present second embodiment, it is possible to estimate at least one of the position or the posture of the moving object 10A even in an environment in which the use of the GNSS is difficult.

(113) In the second embodiment described above, the form example has been shown in which the estimation processing program 42A is stored in the storage 42 of the information processing apparatus 71, but the technology of the present disclosure is not limited to this. For example, the estimation processing program 42A is stored in a storage device of another computer, a server device, or the like connected to the information processing apparatus 71 via a network. The estimation processing program 42A may be downloaded in response to a request of the information processing apparatus 71 and installed in the computer 39.

(114) In addition, it is not necessary to store all of the estimation processing program 42A in the storage device such as another computer or server device connected to the information processing apparatus 71, or in the storage 42, but a part of the estimation processing program 42A may be stored.

(115) In addition, although the computer 39 is built in the information processing apparatus 71 shown in FIG. 12 as an example, the technology of the present disclosure is not limited to this, and for example, the computer 39 may be provided outside the information processing apparatus 71.

First Modification Example

(116) In the first and second embodiments described above, the form example has been described

in which the plurality of wavelength bands are distinguished from each other by using the central wavelength, but the technology of the present disclosure is not limited to this. In the present first modification example, a wavelength having the highest intensity in a certain wavelength band (hereinafter, also referred to as a peak wavelength) is used to distinguish the plurality of wavelength bands. Specifically, a wavelength band having a peak wavelength on a short wavelength side by a designated wavelength from a peak wavelength in the second wavelength band $\Delta f2$ in which the peak wavelength matches a peak wavelength of a blue LED light source is the first wavelength band $\Delta f1$. Similarly, a wavelength band having a peak wavelength on a long wavelength side by a designated wavelength from the peak wavelength of the second wavelength band $\Delta f2$ is the third wavelength band $\Delta f3$. The first wavelength band $\Delta f1$ is an example of a “third adjacent wavelength band” according to the technology of the present disclosure, and the third wavelength band $\Delta f3$ is an example of a “fourth adjacent wavelength band” according to the technology of the present disclosure.

(117) Hereinafter, subtraction processing in a case where the plurality of wavelength bands are distinguished from each other by using the peak wavelength will be described. First, the image processing unit **40B** subtracts the image data of the second wavelength band $\Delta f2$ and the image data of the first wavelength band $\Delta f1$, which has the peak wavelength on the short wavelength side by a designated wavelength from the peak wavelength of the second wavelength band $\Delta f2$. The image processing unit **40B** specifies the in-image position GP based on a result of the subtraction processing. The image data of the first wavelength band $\Delta f1$, which has the peak wavelength on the short wavelength side by the designated wavelength from the peak wavelength of the second wavelength band $\Delta f2$, is an example of “fourth image data” according to the technology of the present disclosure.

(118) In addition, the image processing unit **40B** subtracts the image data of the second wavelength band $\Delta f2$ and the image data of the third wavelength band $\Delta f3$, which has the peak wavelength on the long wavelength side by a designated wavelength from the peak wavelength of the second wavelength band $\Delta f2$. The image processing unit **40B** specifies the in-image position GP based on a subtraction result. The image data of the third wavelength band $\Delta f3$, which has the peak wavelength on the long wavelength side by the designated wavelength from the peak wavelength of the second wavelength band $\Delta f2$, is an example of “fifth image data” according to the technology of the present disclosure.

(119) Also in a case where the fourth wavelength band $\Delta f4$ to the sixth wavelength band $\Delta f6$ are distinguished from each other and in a case where the seventh wavelength band $\Delta f7$ to the ninth wavelength band $\Delta f9$ are distinguished from each other, the fourth wavelength band $\Delta f4$ to the sixth wavelength band $\Delta f6$ and the seventh wavelength band $\Delta f7$ to the ninth wavelength band $\Delta f9$ can be distinguished from each other, respectively, by using the peak wavelength in the same manner as a case where the first wavelength band $\Delta f1$ to the third wavelength band $\Delta f3$ are distinguished from each other. In addition, for the processing of extracting the determination region via the image processing unit **40B**, the wavelength band distinguished by using the peak wavelength similarly can be used.

(120) As described above, in the present first modification example, for example, in a case where the light emitter **37** is a blue LED light source, the in-image position GP is specified based on a result of subtraction processing of the image data obtained by imaging in the second wavelength band $\Delta f2$ and the image data obtained by imaging in the first wavelength band $\Delta f1$. Therefore, with the present configuration, it is realized to specify the in-image position GP more accurately and more quickly than a case in which the in-image position GP is specified by using only the image data obtained by imaging in the second wavelength band $\Delta f2$.

(121) In addition, in the present first modification example, for example, in a case where the light emitter **37** is a blue LED light source, the in-image position GP is specified based on a result of subtraction processing of the image data obtained by imaging in the second wavelength band $\Delta f2$

and the image data obtained by imaging in the third wavelength band $\Delta f3$. Therefore, with the present configuration, it is realized to specify the in-image position GP more accurately and more quickly than a case in which the in-image position GP is specified by using only the image data obtained by imaging in the second wavelength band $\Delta f2$.

Second Modification Example

(122) In the first and second embodiments, the form example has been described in which the results of converting the latitude, the longitude, and the altitude of the GNSS coordinates into the coordinates of the three-dimensional orthogonal coordinate system are used as the positional information of the reference station **36**, but the technology of the present disclosure is not limited to this. In the present second modification example, the positional information of the reference station **36** is obtained by converting the latitude and the longitude of the GNSS coordinates into coordinates of a two-dimensional orthogonal coordinate system. For example, in a case where the moving object **10** moves at a constant height, the latitude and the longitude of the GNSS coordinates can be converted into coordinates of a two-dimensional orthogonal coordinate system and used as the positional information. Examples of a case where the moving object **10** moves at a constant height include a case where the moving object **10** travels on a flat ground and a case where the moving object **10** flies at a constant height.

(123) With the present second modification example, as compared with a case in which the latitude and the longitude are used as they are as the positional information of the reference station **36**, a calculation required for estimating the position and the posture of the moving object **10** is facilitated, and at least one of the position or the posture of the moving object **10** can be estimated more quickly.

(124) In the above-described embodiment, the form example has been described in which the position and the posture of the moving object **10** are estimated in a state in which the reference station **36** is installed, but the technology of the present disclosure is not limited to this. For example, the reference station **36** may be movable. For example, the reference station **36** may comprise a traveling mechanism, and the estimation processing of the position and the posture of the moving object **10** may be performed after the reference station **36** is moved to a position designated in advance. In addition, the reference station **36** may be moved by the worker and then installed at a position designated in advance, and the position and the posture may be estimated in the moving object **10**. In addition, the reference station **36** may not be newly prepared, but may be an existing facility (for example, an illumination lamp or a traffic light) comprising a light source corresponding to the light emitter **37** for estimating the position and the posture of the moving object **10**.

(125) In addition, in the embodiment described above, the form example has been described in which the image processing unit **40B** specifies, in a case where the light emitter **37** is a blue LED light source as an example, the in-image position GP based on a result obtained by subtracting the image data of the first wavelength band $\Delta f1$ or the image data of the third wavelength band $\Delta f3$ from the image data of the second wavelength band $\Delta f2$, but the technology of the present disclosure is not limited to this. For example, the image processing unit **40B** may specify the in-image position GP based on a result obtained by subtracting the image data of the second wavelength band $\Delta f2$ from the image data of the first wavelength band $\Delta f1$ or the third wavelength band $\Delta f3$. In addition, the image processing unit **40B** may also perform the same subtraction processing in a case of specifying the in-image position GP in a case where the light emitter **37** is a yellow LED light source or a red LED light source as an example.

(126) In addition, in the above-described embodiment, the form example has been described in which the position and the posture of the moving object **10** are estimated, but the technology of the present disclosure is not limited to this. For example, only the position of the moving object **10** may be estimated, or only the posture of the moving object **10** may be estimated.

(127) In addition, in the above-described embodiment, the form example has been described in

which the imaging apparatus **30** comprises the pupil division filter **14**, and further each pixel of the image sensor **20** has different combinations of the spectroscopic filter elements **26A**, **26B**, and **26C** and the polarization filter elements **24A**, **24B**, and **24C**, so that light having different characteristics is received. However, the technology of the present disclosure is not limited to this. The imaging apparatus **30** only needs to be capable of imaging in a multispectral method, and may be an imaging apparatus capable of imaging in a multispectral method using a filter wheel.

(128) In addition, in the above-described embodiment, the form example has been described in which the imaging apparatus **30** comprises the fisheye lens **11A** as the objective lens, but the technology of the present disclosure is not limited to this. For example, a plurality of the imaging apparatuses **30** may be provided, and each imaging apparatus **30** may image the periphery of the moving object **10** in synchronization.

(129) In addition, in the above-described embodiment, the form example has been described in which the light emitter **37** provided in the reference station **36** emits light in a visible light band, but the technology of the present disclosure is not limited thereto. The light emitter **37** may emit light in a wavelength band in which the light emitter **37** can be imaged by the imaging apparatus **30**, and may be, for example, an infrared wavelength band.

(130) Moreover, in the embodiment described above, the form example has been described in which the estimation processing program **42A** is stored in the storage **42**, but the technology of the present disclosure is not limited to this. As shown in FIG. **13** as an example, the estimation processing program **42A** may be stored in a portable storage medium **100** such as an SSD or a USB memory. The storage medium **100** is a non-transitory computer-readable storage medium. The estimation processing program **42A**, which is stored in the storage medium **100**, is installed in the computer **39** of the estimation apparatus **38**. The processor **40** executes the estimation processing following the estimation processing program **42A**.

(131) In the embodiment described above, although the computer **39** is illustrated, the technology of the present disclosure is not limited thereto, and a device including an ASIC, an FPGA, and/or a PLD may be applied instead of the computer **39**. Instead of the computer **39**, a combination of a hardware configuration and a software configuration may be used.

(132) Further, as a hardware resource for executing the estimation processing described in the embodiment, the following various processors can be used. Examples of the processors include a CPU that is a general-purpose processor configured to execute software, that is, the program to function as the hardware resource for executing the estimation processing. In addition, an example of the processor is a dedicated electronic circuit which is a processor having a dedicated circuit configuration designed to perform a specific process, such as an FPGA, a PLD, or an ASIC. The memory is built in or connected to any processor, and any processor executes the estimation processing by using the memory.

(133) The hardware resource for executing the estimation processing may be configured by one of these various processors, or may be configured by a combination (for example, a combination of a plurality of FPGAs or a combination of the CPU and the FPGA) of two or more processors of the same type or different types. In addition, the hardware resource for executing the estimation processing may be one processor.

(134) As an example where the hardware resource is configured with one processor, first, there is a form in which one processor is configured with a combination of one or more CPUs and software, and the processor functions as the hardware resource for executing the estimation processing. A second example thereof is a form in which a processor that realizes the functions of the entire system including a plurality of hardware resources for executing the estimation processing with one IC chip is used, as represented by SoC. As described above, the estimation processing is realized by using one or more of the various processors as the hardware resources.

(135) In addition, specifically, an electronic circuit obtained by combining circuit elements, such as semiconductor elements, can be used as the hardware structure of the various processors. The

above-described estimation processing is merely an example. Accordingly, it goes without saying that unnecessary steps may be deleted, new steps may be added, or a processing order may be changed without departing from the gist.

(136) The content of the above description and the content of the drawings are detailed description of portions according to the technology of the present disclosure, and are merely examples of the technology of the present disclosure. For example, the above description relating to configurations, functions, operations, and advantageous effects is description relating to an example of configurations, functions, operations, and advantageous effects of the portions according to the technology of the present disclosure. Thus, it is needless to say that unnecessary portions may be deleted, new elements may be added, or replacement may be made to the content of the above description and the content of the drawings without departing from the gist of the technology of the present disclosure. Furthermore, to avoid confusion and to facilitate understanding of the portions according to the technology of the present disclosure, description relating to common technical knowledge and the like that does not require particular description to enable implementation of the technology of the present disclosure is omitted from the content of the above description and from the content of the drawings.

(137) In this specification, “A and/or B” is synonymous with “at least one of A or B”. That is, “A and/or B” may refer to A alone, B alone, or a combination of A and B. Furthermore, in this specification, a similar concept to “A and/or B” applies to a case in which three or more matters are expressed by linking the matters with “and/or”.

(138) The disclosure of Japanese Patent Application No. 2021-161787 filed on Sep. 30, 2021, is incorporated in this specification by reference in its entirety.

(139) All cited documents, patent applications, and technical standards described in the specification are incorporated by reference in the specification to the same extent as in a case where each individual cited document, patent application, or technical standard is specifically and individually indicated to be incorporated by reference.

Claims

1. An estimation apparatus comprising: a processor that is configured to: acquire positional information of a plurality of reference stations each having a light emitter that emits light in wavelength bands different from each other; acquire image data obtained by imaging an imaging scene including the light emitter via an imaging apparatus mounted on a moving object, the image data including a plurality of image data groups obtained by imaging the imaging scene via the imaging apparatus in a plurality of the wavelength bands; specify an in-image position of a light emitter of one reference station among the plurality of reference stations, based on a result of subtraction processing of first image data obtained by imaging the imaging scene in a light emitter wavelength band, which is a wavelength band in which the light emitter of the one reference station emits light, and second image data obtained by imaging the imaging scene in a first adjacent wavelength band, which has a central wavelength on one of a long wavelength side or a short wavelength side by a designated wavelength from a central wavelength of the light emitter wavelength band; and estimate at least one of a position of the moving object or a posture of the moving object based on the in-image position and the positional information of the plurality of reference stations.

2. The estimation apparatus according to claim 1, wherein the processor is configured to: specify the in-image position of the light emitter of the one reference station, based on a result of subtraction processing of the first image data and third image data obtained by imaging the imaging scene in a second adjacent wavelength band, which has a central wavelength on another side with respect to the first adjacent wavelength band by a designated wavelength from the central wavelength of the light emitter wavelength band.

3. The estimation apparatus according to claim 1, wherein the image data includes a plurality of image data groups obtained by imaging the imaging scene via the imaging apparatus in a plurality of the wavelength bands, and the processor is configured to: specify the in-image position of a light emitter of one reference station among the plurality of reference stations, based on a result of subtraction processing of first image data obtained by imaging in a light emitter wavelength band, which is a wavelength band in which the light emitter of the one reference station emits light, and fourth image data obtained by imaging the imaging scene in a third adjacent wavelength band, which has a wavelength having the highest intensity on one of a long wavelength side or a short wavelength side by a designated wavelength from a wavelength having the highest intensity in the light emitter wavelength band.
4. The estimation apparatus according to claim 3, wherein the processor is configured to: specify the in-image position of the light emitter of the one reference station, based on a result of subtraction processing of the first image data and fifth image data obtained by imaging the imaging scene in a fourth adjacent wavelength band, which has a wavelength having the highest intensity on another side with respect to the third adjacent wavelength band by a designated wavelength from the wavelength having the highest intensity in the light emitter wavelength band.
5. The estimation apparatus according to claim 1, wherein the image data includes a plurality of image data groups obtained by imaging the imaging scene via the imaging apparatus in a plurality of the wavelength bands, and the processor is configured to: specify the in-image position of a light emitter of one reference station among the plurality of reference stations, based on sixth image data obtained by imaging the imaging scene in a wavelength band different from a light emitter wavelength band in which the light emitter of the one reference station emits light.
6. The estimation apparatus according to claim 1, wherein the positional information is obtained by converting a latitude and a longitude of each of the plurality of reference stations into coordinates in a two-dimensional orthogonal coordinate system.
7. The estimation apparatus according to claim 1, wherein the positional information is obtained by converting a latitude, a longitude, and an altitude of each of the plurality of reference stations into coordinates in a three-dimensional orthogonal coordinate system.
8. The estimation apparatus according to claim 1, wherein the plurality of reference stations are three or more.
9. An imaging apparatus comprising: an image sensor; and the estimation apparatus according to claim 1, wherein the estimation apparatus is configured to estimate at least one of the position of the moving object or the posture of the moving object using an image obtained by imaging the imaging scene via the image sensor.
10. The imaging apparatus according to claim 9, wherein the image sensor is an image sensor capable of imaging in a multispectral method.
11. A moving object comprising: an imaging apparatus; and an estimation apparatus that is configured to: acquire positional information of a plurality of reference stations each having a light emitter that emits light in wavelength bands different from each other; acquire image data obtained by imaging an imaging scene including the light emitter via the imaging apparatus, the image data including a plurality of image data groups obtained by imaging the imaging scene via the imaging apparatus in a plurality of the wavelength bands; specify an in-image position of a light emitter of one reference station among the plurality of reference stations, based on a result of subtraction processing of first image data obtained by imaging the imaging scene in a light emitter wavelength band, which is a wavelength band in which the light emitter of the one reference station emits light, and second image data obtained by imaging the imaging scene in a first adjacent wavelength band, which has a central wavelength on one of a long wavelength side or a short wavelength side by a designated wavelength from a central wavelength of the light emitter wavelength band; and estimate at least one of a position of the moving object or a posture of the moving object based on the in-image position and the positional information of the plurality of reference stations.

12. An estimation system comprising: a moving object on which an imaging apparatus is mounted; an estimation apparatus; and a plurality of reference stations each having a light emitter that emits light in wavelength bands different from each other, wherein the estimation apparatus is configured to: acquire positional information of the plurality of reference stations; acquire image data obtained by imaging an imaging scene including the light emitter via the imaging apparatus, the image data including a plurality of image data groups obtained by imaging the imaging scene via the imaging apparatus in a plurality of the wavelength bands; specify an in-image position of a light emitter of one reference station among the plurality of reference stations, based on a result of subtraction processing of first image data obtained by imaging the imaging scene in a light emitter wavelength band, which is a wavelength band in which the light emitter of the one reference station emits light, and second image data obtained by imaging the imaging scene in a first adjacent wavelength band, which has a central wavelength on one of a long wavelength side or a short wavelength side by a designated wavelength from a central wavelength of the light emitter wavelength band; and estimate at least one of a position of the moving object or a posture of the moving object based on an in-image position and the positional information of the plurality of reference stations.

13. An estimation method comprising: acquiring positional information of a plurality of reference stations each having a light emitter that emits light in wavelength bands different from each other; acquiring image data obtained by imaging an imaging scene including the light emitter via an imaging apparatus mounted on a moving object, the image data including a plurality of image data groups obtained by imaging the imaging scene via the imaging apparatus in a plurality of the wavelength bands; specifying an in-image position of a light emitter of one reference station among the plurality of reference stations, based on a result of subtraction processing of first image data obtained by imaging the imaging scene in a light emitter wavelength band, which is a wavelength band in which the light emitter of the one reference station emits light, and second image data obtained by imaging the imaging scene in a first adjacent wavelength band, which has a central wavelength on one of a long wavelength side or a short wavelength side by a designated wavelength from a central wavelength of the light emitter wavelength band; and estimating at least one of a position of the moving object or a posture of the moving object based on the in-image position and the positional information of the plurality of reference stations.

14. A non-transitory storage medium storing a program causing a computer to execute a process comprising: acquiring positional information of a plurality of reference stations each having a light emitter that emits light in wavelength bands different from each other; acquiring image data obtained by imaging an imaging scene including the light emitter via an imaging apparatus mounted on a moving object, the image data including a plurality of image data groups obtained by imaging the imaging scene via the imaging apparatus in a plurality of the wavelength bands; specifying an in-image position of a light emitter of one reference station among the plurality of reference stations, based on a result of subtraction processing of first image data obtained by imaging the imaging scene in a light emitter wavelength band, which is a wavelength band in which the light emitter of the one reference station emits light, and second image data obtained by imaging the imaging scene in a first adjacent wavelength band, which has a central wavelength on one of a long wavelength side or a short wavelength side by a designated wavelength from a central wavelength of the light emitter wavelength band; and estimating at least one of a position of the moving object or a posture of the moving object based on the in-image position and the positional information of the plurality of reference stations.
