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FORESTRY MANAGEMENT SYSTEM AND FORESTRY MANAGEMENT METHOD

Abstract

Low-altitude observation equipment includes a distance measurement device that generates a distance map and a position measurement device that measures a position of the low-altitude observation equipment. The low-altitude observation equipment moves in a region of a forest near a ground surface where there are no branches. A data acquisition unit acquires a low-altitude distance map generated by the distance measurement device and the position of the low-altitude observation equipment from the low-altitude observation equipment. A position specifying unit specifies a position of a tree, based on a distance from the low-altitude observation equipment to the tree specified based on the map, and on the position of the low-altitude observation equipment. An identification unit acquires identification information for identifying an individual of the tree based on the position of the tree. A recording unit records low-altitude tree information, which is tree information of a portion of the individual lower than branches.

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Background/Summary

TECHNICAL FIELD
[0001] The present disclosure relates to a forestry management system and a forestry management method.
[0002] Priority is claimed on Japanese Patent Application No. 2022-069071, filed Apr. 19, 2022, the content of which is incorporated herein by reference.
BACKGROUND ART
[0003] Patent Document 1 discloses a technology for recognizing a terrain of a work site based on images of the work site acquired by being captured by an unmanned aircraft and for planning a moving route of forestry machine for timber harvesting.
CITATION LIST
Patent Document
[0004] Patent Document 1: U.S. Pat. No. 10,322,803
SUMMARY OF INVENTION
Technical Problem
[0005] In a case in which trees are densely grown in a forest, a canopy may be shown in an image captured from a sky, and states of trees below the canopy may not be shown. Additionally, there is a possibility that trees not forming the canopy are not shown in the image captured from the sky, making it impossible to manage conditions of these trees.
[0006] An object of the present disclosure is to provide a forestry management system and a forestry management method which can manage conditions of trees forming a forest.
Solution to Problem
[0007] An aspect of the present invention relates to a forestry management system including: a data acquisition unit configured to acquire a low-altitude distance map generated by a distance measurement device that generates a distance map and a position of low-altitude observation equipment from the low-altitude observation equipment, the low-altitude observation equipment moving in a region of a forest near a ground surface where there are no branches and including the distance measurement device and a position measurement device that measures the position of the low-altitude observation equipment; a position specifying unit configured to specify a position of a tree, based on a distance from the low-altitude observation equipment to the tree specified based on the low-altitude distance map, and on the position of the low-altitude observation equipment; an identification unit configured to acquire identification information for identifying an individual of the tree based on the position of the tree; and a recording unit configured to record low-altitude tree information, which is tree information of a portion of the individual lower than branches that is measured based on the low-altitude distance map, in a database in association with the identification information.
Advantageous Effects of Invention
[0008] According to the above aspect, a forestry management system can manage conditions of trees forming a forest.

Description

BRIEF DESCRIPTION OF DRAWINGS

[0009] FIG. **1** is a schematic diagram showing a forestry management system according to a first embodiment.

[0010] FIG. **2** is a configuration diagram showing an appearance of low-altitude observation equipment according to the first embodiment.

[0011] FIG. **3** is a configuration diagram showing an appearance of high-altitude observation equipment according to the first embodiment.

[0012] FIG. **4** is a configuration diagram showing an appearance of a forestry machine according to the first embodiment.

[0013] FIG. **5** is a schematic block diagram showing a configuration of a forestry management device according to the first embodiment.

[0014] FIG. **6** is a diagram showing a database stored in a storage according to the first embodiment.

[0015] FIG. **7** is a flowchart showing an update process of tree information performed by the forestry management device according to the first embodiment.

[0016] FIG. **8** is a flowchart showing a generation process of a felling plan performed by the forestry management device according to the first embodiment.

[0017] FIG. **9** is a schematic block diagram showing a configuration of a forestry management device according to a second embodiment.

DESCRIPTION OF EMBODIMENTS

First Embodiment

<<Configuration of Forestry Management System>>

[0018] Hereinafter, embodiments will be described in detail with reference to the drawings.

[0019] FIG. **1** is a schematic diagram showing a forestry management system **1** according to a first embodiment.

[0020] The forestry management system **1** identifies individuals of trees growing in a forest F and manages a condition of each individual. Additionally, the forestry management system **1** generates a harvest plan based on the conditions of the trees, and carries out harvesting of the trees. The forestry management system **1** includes low-altitude observation equipment **10**, high-altitude observation equipment **30**, a forestry machine **50**, and a forestry management device **70**.

[0021] The low-altitude observation equipment **10** travels on the ground of the forest F via remote operation and observes the trunks of trees growing in the forest F and the ground surface. As shown in FIG. **1**, the low-altitude observation equipment **10** according to the first embodiment may be a robot with a continuous track. The low-altitude observation equipment **10** according to another embodiment may travel via wheels or legs, or may be a drone that flies in the air. When the low-altitude observation equipment **10** flies, the low-altitude observation equipment **10** flies at an altitude lower than the canopy of the forest F. The canopy refers to the part of the forest where branches are dense. That is, the low-altitude observation equipment **10** flies in a region of the forest F near the ground surface where there are no branches.

[0022] The high-altitude observation equipment **30** flies in the sky of the forest F via remote operation and observes the crowns of trees growing in the forest F. The crown refers to the portion where the branches of the tree are dense. The remote operation may involve the operation via the operator with a controller C**3** in real time, or may involve flying along a route set in advance by the operator using the controller C**3**. That is, the high-altitude observation equipment **30** flies at an altitude higher than the canopy of the forest F. As shown in FIG. **1**, the high-altitude observation equipment **30** according to the first embodiment may be a drone.

[0023] The forestry machine **50** is a work machine that grips a trunk of the tree and then fells the tree and that can travel while gripping the trunk. As a result, the forestry machine **50** can collect the timber at a predetermined location. The forestry machine **50** may be a feller buncher or a harvester.

[0024] The forestry management device **70** receives measurement data from the low-altitude observation equipment **10** and from the high-altitude observation equipment **30**, identifies individuals of trees inhabiting the forest F, and records the condition of each individual. In addition, the forestry management device **70** generates a harvest plan based on the conditions of the trees and transmits an instruction signal to the forestry machine **50**. The forestry machine **50** operates based on the instruction signal received from the forestry management device **70**. The low-altitude observation equipment **10**, the high-altitude observation equipment **30**, the forestry machine **50**, and the forestry management device **70** are connected to each other via a communication network N such as the Internet. The forestry management device **70** may be provided remotely from the low-altitude observation equipment **10**, the high-altitude observation equipment **30**, and the forestry machine **50**.

<<Configuration of Low-Altitude Observation Equipment **10**>>
[0025] FIG. **2** is a configuration diagram showing an appearance of the low-altitude observation equipment **10** according to the first embodiment.

[0026] The low-altitude observation equipment **10** includes an undercarriage **11** and a fuselage **12**. The undercarriage **11** supports the fuselage **12** to be capable of traveling. The undercarriage **11** of the low-altitude observation equipment **10** may be, for example, a continuous track driven by a power of a motor.

[0027] The fuselage **12** includes a distance measurement device **121**, a position measurement device **122**, a posture measurement device **123**, an illuminance sensor **124**, a battery **125**, a control device **126**, and an imaging device **127**.

[0028] The distance measurement device **121** generates a distance map that maps the distance to the subject within the field of view. Examples of the distance measurement device **121** include a stereo camera, a ToF camera, a pattern projection camera, and LiDAR. The imaging device **127** captures a color image of the subject. The distance measurement device **121** and the imaging device **127** are provided so that lines of sight thereof face the front of the fuselage **12**. When the distance measurement device **121** can obtain a color image, for example, when the distance measurement device **121** is a stereo camera, the fuselage **12** need not include the imaging device **127**. The distance map is data that maps the distances between a plurality of points on a two-dimensional plane. The distance map includes, for example, three-dimensional shape data generated by LiDAR or the like and a distance image generated by a stereo camera.

[0029] The position measurement device **122** includes an antenna that receives a position measurement signal from a GNSS, and measures the position of the low-altitude observation equipment **10** based on the position measurement signal received via the antenna. The position measurement device **122** outputs position data indicating the measured position to the control device **126**. The position of the low-altitude observation equipment **10** is represented by a three-dimensional global coordinate system. In a case in which the position measurement device **122** includes a plurality of antennas, the position measurement device **122** can measure the azimuth direction in which the low-altitude observation equipment **10** faces.

[0030] The posture measurement device **123** measures a posture of the fuselage **12**. Specifically, the posture measurement device **123** measures the pitch angle, roll angle, and yaw angle of the fuselage **12** based on the acceleration and angular acceleration measured by the inertial measurement unit (IMU) built in the posture measurement device **123**. In a case in which the IMU includes a geomagnetic sensor, the posture measurement device **123** can measure the posture in the global coordinate system. Meanwhile, the posture measurement device **123** may measure the posture in the local coordinate system based on the fuselage **12**, and convert this posture into the global coordinate system based on the azimuth direction in which the fuselage **12** faces, which is measured by the position measurement device **122**.

[0031] The illuminance sensor **124** is provided on the upper surface of the fuselage **12** and measures the brightness around the low-altitude observation equipment **10**.

[0032] The battery **125** is the power source for the undercarriage **11** and the control device **126**.

[0033] The control device **126** receives the control signal for the undercarriage **11** from a controller C**1**, which remotely operates the low-altitude observation equipment **10**, and drives the undercarriage **11** in response to the control signal. The controller C**1** may be a PC or a smartphone. The control device **126** transmits the image of the distance map generated by the distance measurement device **121** or the image captured by the imaging device **127** to the controller C**1**. Additionally, the control device **126** receives a measurement instruction signal that issues the instruction for measurement of the condition of the tree from the controller C**1**. For example, the operator operates the controller C**1** to orient the front of the low-altitude observation equipment **10** towards the tree to be measured and transmits the measurement instruction signal. That is, the operator controls the posture of the low-altitude observation equipment **10** so that the tree is shown in the center of the image, and transmits the measurement instruction signal.

[0034] The control device **126** transmits the measurement data acquired by the distance measurement device **121**, the position measurement device **122**, the posture measurement device **123**, and the illuminance sensor **124** to the forestry management device **70** in association with the measured time after receiving the measurement instruction signal.

<<Configuration of High-Altitude Observation Equipment **30**>>

[0035] FIG. **3** is a configuration diagram showing an appearance of the high-altitude observation equipment **30** according to the first embodiment.

[0036] The high-altitude observation equipment **30** includes a fuselage **31** and a propeller **32**. The propeller **32** is provided on an upper portion of the fuselage **31** and generates a lift through rotation. The fuselage **31** is provided with a distance measurement device **311**, a multispectral camera **312**, a position measurement device **313**, a posture measurement device **314**, an illuminance sensor **315**, a battery **316**, and a control device **317**.

[0037] The distance measurement device **311** generates a distance map that maps the distance to the subject within the field of view. Examples of the distance measurement device **311** include a stereo camera, a ToF camera, and LiDAR. The distance measurement device **311** is provided so that a line of sight thereof faces below the fuselage **31**.

[0038] The multispectral camera **312** measures the intensity of reflected light across a plurality of wavelengths ranging from the visible region to the infrared region, and generates a data cube representing the captured image for each wavelength. The data cube is three-dimensional data in which two-dimensional image data represented by the X-axis and the Y-axis are arranged on the wavelength axis. The multispectral camera **312** acquires an image in the visible region used for at least photosynthesis and an image in the near infrared region not used for photosynthesis. The multispectral camera **312** is provided so that a line of sight thereof faces below the fuselage **31**.

[0039] The position measurement device **313** includes an antenna that receives a position measurement signal from a GNSS, and measures the position of the high-altitude observation equipment **30** based on the position measurement signal received via the antenna. The position measurement device **313** outputs position data indicating the measured position to the control device **317**. The position of the high-altitude observation equipment **30** is represented by a three-dimensional global coordinate system. In a case in which the position measurement device **313** includes a plurality of antennas, the position measurement device **313** can measure the azimuth direction in which the high-altitude observation equipment **30** faces.

[0040] The posture measurement device **314** measures a posture of the fuselage **31**. Specifically, the posture measurement device **314** measures the pitch angle, roll angle, and yaw angle of the fuselage **31** based on the acceleration and angular acceleration measured by the IMU built in the posture measurement device **314**. In a case in which the IMU includes a geomagnetic sensor, the posture measurement device **314** can measure the posture in the global coordinate system. Meanwhile, the posture measurement device **314** may measure the posture in the local coordinate system based on the fuselage **31**, and convert this posture into the global coordinate system based

on the azimuth direction in which the fuselage **31** faces, which is measured by the position measurement device **313**.

[0041] The illuminance sensor **315** is provided on the upper surface of the fuselage **31** and measures the brightness around the high-altitude observation equipment **30**.

[0042] The battery **316** is the power source for the motor that drives the propeller **32** and the control device **317**.

[0043] The control device **317** receives the control signal from the controller C**3**, which remotely operates the high-altitude observation equipment **30**, and drives the propeller **32** in response to the control signal. The controller C**3** may be a PC or a smartphone. The control device **317** may transmit an image of the distance map captured by the distance measurement device **311** or a color image, which is a converted one of the data cube captured by the multispectral camera **312**, to the controller C**3**. In addition, in another embodiment, the high-altitude observation equipment **30** may move in conjunction with the low-altitude observation equipment **10** while matching the plane position thereof that of the low-altitude observation equipment **10**. In this case, the control device **317** may determine the movement direction based on the position data measured by the position measurement device **313** and on the position data of the low-altitude observation equipment **10**, and drive the propeller **32**. Additionally, the control device **317** receives a measurement instruction signal that issues the instruction for measurement of the condition of the tree below from the controller C**3**. That is, the operator operates the controller C**3** to position the high-altitude observation equipment **30** directly above the tree to be measured and transmits the measurement instruction signal. That is, the operator controls the high-altitude observation equipment **30** so that the tree to be measured is shown in the center of the image, and transmits the measurement instruction signal.

[0044] The control device **317** transmits the measurement data acquired by the distance measurement device **311**, the multispectral camera **312**, the position measurement device **313**, the posture measurement device **314**, and the illuminance sensor **315** to the forestry management device **70** in association with the measured time.

<<Configuration of Forestry Machine **50**>>

[0045] FIG. **4** is a configuration diagram showing an appearance of the forestry machine **50** according to the first embodiment. The forestry machine **50** includes a vehicle body **51**, an undercarriage **52**, work equipment **53**, and a control device **54**.

[0046] The undercarriage **52** supports the vehicle body **51** to be capable of traveling. The undercarriage **52** is a continuous track driven by a power of an engine. Meanwhile, in another embodiment, the undercarriage **52** may include a wheel driven by the power of the engine.

[0047] A position measurement device **511** for measuring a position of the vehicle body **51** is provided in the vehicle body **51**. The position measurement device **511** includes an antenna that receives a position measurement signal from a GNSS, and measures the position of the vehicle body **51** based on the position measurement signal received via the antenna. The position measurement device **511** outputs position data indicating the measured position to the control device **54**. The position of the vehicle body **51** is represented by a three-dimensional global coordinate system.

[0048] The work equipment **53** is used for gripping and felling the tree. The work equipment **53** is provided at a front portion of the vehicle body **51**. The work equipment **53** includes a boom **531**, an arm **532**, a head **533**, an arm cylinder **534**, and a head cylinder **535**.

[0049] The base end portion of the boom **531** is attached to a rear portion of the vehicle body **51**. The boom **531** is rotated by a hydraulic motor (not shown). A base end portion of the arm **532** is attached to a distal end portion of the boom **531** to be rotatable about an axis extending in a width direction of the vehicle body **51**. The head **533** is attached to the arm **532** to be rotatable about a first axis extending in the width direction of the vehicle body **51** and rotatable about a second axis orthogonal to the first axis. A grapple **5331** for gripping the tree is provided on an upper portion of

the head **533**. A circular saw **5332** for felling the tree is provided parallel with the grapple **5331** at a lower portion of the head **533**.

[0050] The arm cylinder **534** and the head cylinder **535** are hydraulic cylinders. A base end portion of the arm cylinder **534** is attached to the boom **531**. A distal end portion of the arm cylinder **534** is attached to the arm **532**. The arm **532** is raised and lowered by the arm cylinder **534** being expanded and contracted by hydraulic oil. A base end portion of the head cylinder **535** is attached to the arm **532**. A distal end portion of the head cylinder **535** is attached to the head **533**. The head cylinder **535** is expanded and contracted by the hydraulic oil, whereby the head **533** rotates about the first axis.

[0051] The control device **54** generates a driving signal for driving the undercarriage **52** and the work equipment **53**, and controls actuators of the undercarriage **52** and the work equipment **53**. The control device **54** includes a communication device that performs communication with the forestry management device **70** via the communication network N. Based on the instruction signal received from the forestry management device **70** via the communication network N and on the position data measured by the position measurement device **511**, the control device **54** controls the undercarriage **52** and the work equipment **53**. The instruction signal received from the forestry management device **70** includes the traveling route within the forest F, as well as identification information of the tree to be felled and information indicating the position of the tree. The control device **54** causes the undercarriage **52** to travel along the traveling route based on the position data measured by the position measurement device **511**. In addition, the control device **54** causes the undercarriage **52** to travel such that the undercarriage **52** faces the tree straight based on the position data, and drives the work equipment **53**. When felling of the tree is completed, the control device **54** transmits a felling notification signal, which includes the identification information of the tree, to the forestry management device **70**.

<<Configuration of Forestry Management Device **70**>>

[0052] FIG. **5** is a schematic block diagram showing a configuration of the forestry management device **70** according to the first embodiment.

[0053] The forestry management device **70** is a computer including a processor **71**, a main memory **73**, a storage **75**, and an interface **77**. The storage **75** stores a program. The processor **71** reads out the program from the storage **75**, loads the program in the main memory **73**, and executes a process according to the program.

[0054] In another embodiment, the forestry management device **70** may include a custom large scale integrated circuit (LSI), such as a programmable logic device (PLD), in addition to the above-described configuration or instead of the above-described configuration. Exemplary examples of the PLD include a programmable array logic (PAL), a generic array logic (GAL), a complex programmable logic device (CPLD), and a field programmable gate array (FPGA). In this case, some or all of the functions realized by the processor **71** may be realized by an integrated circuit. The integrated circuit is also included in the example of the processor.

[0055] The forestry management device **70** is connected to a communication network N via the interface **77**. The forestry management device **70** is connected to an input/output device (not shown) via the interface **77**.

[0056] Exemplary examples of the storage **75** include a hard disk drive (HDD), a solid state drive (SSD), and a non-volatile memory. The storage **75** may be an internal medium directly connected to a bus of the forestry management device **70**, or may be an external medium connected to the forestry management device **70** via the interface **77**. The storage **75** is a non-transitory tangible storage medium.

[0057] The storage **75** is configured with a database **751** that stores information related to the individuals of the trees growing in the forest F. FIG. **6** is a diagram showing a database stored in a storage according to the first embodiment. Specifically, in the database **751**, for each individual of tree, the ID, position, species, height, diameter, activity, defect, surrounding relative illuminance,

tree age, timber volume, image, presence or absence of tree planting, and felling status are stored in association with each other. The ID is identification information for identifying the individual of tree. The position is a three-dimensional position in the global coordinate system where the tree exists. That is, the position is the latitude, longitude, and elevation of the ground surface on which the tree stands. The height is the length from the ground surface to the treetop. The activity is an index value of the photosynthetic activity of the tree. The activity is represented by, for example, the normalized difference vegetation index (NDVI), which is the ratio of the amount of reflected light in the red wavelength region to the amount of reflected light in the near infrared region. The defect represents the presence or absence of peeling of bark, the presence or absence of rot, or the like. The relative illuminance is the ratio of the illuminance below the canopy to the illuminance above the canopy. The felling status indicates whether or not the tree has been felled. The presence or absence of tree planting may be obtained from an external database (not shown), and in this case, data related to tree planting, such as information related to the time and position of tree planting and species, may be obtained, and the tree age, position, and species in the database **751** may be updated.

[0058] The processor **71** executes a program to function as a data acquisition unit **711**, a position specifying unit **712**, a fallen tree determination unit **713**, an identification unit **714**, a treetop altitude calculation unit **715**, a tree height calculation unit **716**, a diameter calculation unit **717**, a species specifying unit **718**, a defect specifying unit **719**, an activity calculation unit **720**, a relative illuminance calculation unit **721**, a recording unit **722**, a felling plan generation unit **723**, and a felling instruction unit **724**.

[0059] The data acquisition unit **711** acquires measurement data from the low-altitude observation equipment **10** and from the high-altitude observation equipment **30**. That is, the data acquisition unit **711** acquires the distance map (low-altitude captured data) acquired by the low-altitude observation equipment **10**, as well as the time, position, posture, and illuminance at the time of capturing. The distance map of the low-altitude observation equipment **10** may be captured such that the tree is shown in the center. Hereinafter, the central point in the distance map is also referred to as the point of interest. In another embodiment, the processor **71** may analyze the distance map or the image captured by the imaging device **127** to specify a point where a tree exists as the point of interest. For example, when a target object with a shape similar to a trunk of tree, a semi-cylindrical shape, or the like is recognized in the measured distance map, the target object may be recognized as a tree. Additionally, when, in the image, the target object similar to a tree is captured in the direction of image, the target object may be recognized as a tree. In addition, the data acquisition unit **711** acquires the distance map and the data cube (high-altitude captured data) acquired by the high-altitude observation equipment **30**, as well as the time, position, posture, and illuminance at the time of capturing.

[0060] The position specifying unit **712** specifies the three-dimensional position of the lower end portion of the tree from the position and posture of the low-altitude observation equipment **10**, as well as the distance map acquired by the data acquisition unit **711**. Specifically, the data acquisition unit **711** specifies the three-dimensional position of the lower end portion of the tree by the following procedure. The position specifying unit **712** specifies the portion where the semi-cylindrical structure is shown via pattern matching of the distance map of the low-altitude observation equipment **10**. Next, the position specifying unit **712** specifies the point where the end portion of the structure in the axial direction is shown. Since the treetop is not shown in the field of view of the distance measurement device **121** of the low-altitude observation equipment **10**, it is estimated that the end portion of the tree in the axial direction is the lower end portion of the tree. The position specifying unit **712** specifies the three-dimensional position of the specified point based on the position and posture of the low-altitude observation equipment **10**. In a case in which the tree is a living tree, the position of the lower end portion of the tree is the position of the ground surface on which the tree stands. The altitude of the ground surface on which the tree stands is one

piece of tree information of a portion lower than the trunk.

[0061] The fallen tree determination unit **713** determines whether the tree specified by the position specifying unit **712** is a fallen tree or a living tree from the distance map of the low-altitude observation equipment **10** acquired by the data acquisition unit **711**. Specifically, the fallen tree determination unit **713** specifies the axial direction of the tree from the distance map, and determines that the tree is a fallen tree when the angle formed by the axial direction and the horizontal plane is less than a predetermined fallen tree determination threshold value, that is, when the axial direction of the tree is close to horizontal. On the other hand, the fallen tree determination unit **713** determines that the tree is a living tree when the angle formed by the axial direction of the tree and the horizontal plane is equal to or greater than the fallen tree determination threshold value. The fallen tree determination unit **713** may record the position at which the tree determined to be a fallen tree exists in the database **751**.

[0062] The identification unit **714** acquires the ID of the tree determined to be a living tree by the fallen tree determination unit **713**. Specifically, the identification unit **714** specifies the individual that is closest to the latitude and longitude of the tree specified by the position specifying unit **712** and that is not felled from the database **751**. When the distance to the individual is less than a predetermined error threshold value, the identification unit **714** determines that the tree shown in the distance map is the individual, and acquires the ID of the individual. On the other hand, when the distance to the closest individual is equal to or greater than the error threshold value, the identification unit **714** determines that the tree shown in the distance map is a new individual, and assigns a new ID to the tree. In a case in which the identification unit **714** assigns a new ID to the tree, the identification unit **714** records the plane position specified by the position specifying unit **712** and the ID in association with each other in the database **751**.

[0063] In addition, the treetop altitude calculation unit **715** calculates the altitude of the treetop of tree from the distance map of the high-altitude observation equipment **30** acquired by the data acquisition unit **711**. Specifically, the treetop altitude calculation unit **715** calculates the altitude of the treetop of tree by the following procedure. The treetop altitude calculation unit **715** specifies the point where the treetop is shown from the distance map of the high-altitude observation equipment **30**. For example, the treetop altitude calculation unit **715** may specify a point where the height in the distance map is the maximum as the point where the treetop is shown. Next, the treetop altitude calculation unit **715** calculates the three-dimensional position of the point at which the treetop is shown, based on the position and posture of the high-altitude observation equipment **30** during capturing. The identification unit **714** specifies the individual that is closest to the latitude and longitude of the point where the treetop is shown and that is not felled from the database **751**. The treetop altitude calculation unit **715** specifies the calculated altitude of the three-dimensional position as the altitude of the treetop of the specified individual.

[0064] The tree height calculation unit **716** calculates, as the height of the tree, the difference between the altitude of the ground surface on which the tree stands, which is calculated by the position specifying unit **712**, and the altitude of the treetop calculated by the treetop altitude calculation unit **715**.

[0065] The diameter calculation unit **717** calculates the diameter of the tree from the distance map of the low-altitude observation equipment **10** acquired by the data acquisition unit **711**. For example, the diameter calculation unit **717** specifies the pixels at the left and right ends of the tree in the width direction orthogonal to the axial direction of the tree in the distance map, and calculates the distance between the positions indicated by these pixels as the diameter of the tree. The diameter of the tree is one piece of tree information of the portion lower than the trunk.

[0066] The species specifying unit **718** specifies the species of the tree based on the image captured by the imaging device **127** of the low-altitude observation equipment **10**. For example, the species specifying unit **718** may specify the species of the tree by inputting the image captured by the imaging device **127** of the low-altitude observation equipment **10** into a learned model that receives

the image as input and that outputs the species of the tree shown in the image. Additionally, for example, the species specifying unit **718** may specify the species of the tree via template matching using a template image of the bark that is prepared in advance for each species of tree. When a color image can be obtained, for example, when the distance measurement device **121** is a stereo camera, the species specifying unit **718** may specify the species of the tree based on the image obtained by the distance measurement device **121**.

[0067] The defect specifying unit **719** specifies the presence or absence of defect of trunk and the type of defect based on the image captured by the imaging device **127** of the low-altitude observation equipment **10**. Examples of the type of defect include peeling of the bark or the rot. For example, the defect specifying unit **719** may specify the presence or absence of defect of the tree by inputting the image captured by the imaging device **127** of the low-altitude observation equipment **10** into a learned model that receives the image as input and that outputs the presence or absence of peeling of bark and the presence or absence of rot in the tree shown in the image. Additionally, for example, the defect specifying unit **719** may specify the defect of the tree via template matching using a template image that is prepared in advance for each defect of tree. The information related to the defect of trunk is one piece of tree information of the portion lower than the trunk. When a color image can be obtained, for example, when the distance measurement device **121** is a stereo camera, the defect specifying unit **719** may specify the presence or absence of defect of the tree based on the image obtained by the distance measurement device **121**.

[0068] The activity calculation unit **720** calculates the activity of the tree based on the data cube of the high-altitude observation equipment **30**. For example, the activity calculation unit **720** specifies a pixel in the data cube where the treetop specified by the treetop altitude calculation unit **715** is shown, and calculates the ratio of the brightness in the red region to the brightness in the infrared region of that pixel as the activity of the tree.

[0069] The relative illuminance calculation unit **721** calculates the relative illuminance based on the measurement value of illuminance of the low-altitude observation equipment **10** and on the measurement value of illuminance of the high-altitude observation equipment **30**. The relative illuminance calculation unit **721** extracts the value corresponding to the time closest to the time at which the low-altitude observation equipment **10** measures the illuminance from the time series of the measurement value of the illuminance of the high-altitude observation equipment **30**, and calculates the relative illuminance. Since the relative illuminance varies depending on the altitude of the sun or the weather, the relative illuminance calculation unit **721** may absorb the variation by, for example, obtaining an average of a plurality of measurement values obtained at different times. The relative illuminance is one piece of tree information of the portion lower than the trunk.

[0070] The recording unit **722** records, in the database **751**, the date and time, species, height, diameter, activity, defect, surrounding relative illuminance, tree age, timber volume, and image captured by the imaging device **127** of the low-altitude observation equipment **10** in association with the ID acquired by the identification unit **714**. When the date on which the tree is planted is recorded as information during tree planting, the tree age can be calculated from the date and the current date and time. In addition, the tree age may be obtained from the diameter, the image analysis of the image captured by the imaging device **127**, or the like. The timber volume may be calculated using a predetermined calculation formula from the height, diameter, species, and the like. The recording unit **722** may further record the three-dimensional position of the ground surface on which the tree stands in the database **751**. The recording unit **722** adds data without overwriting past data in order to manage the growth history of the tree.

[0071] The felling plan generation unit **723** generates a felling plan for thinning via forestry machine **50** based on the conditions of the trees recorded in database **751**. The felling plan generation unit **723** receives the input of the target range and the felling rate from the user, and determines the individuals to be felled based on the heights, activities, health conditions, and surrounding relative illuminances of the trees growing in the target range. For example, the felling

plan generation unit **723** calculates a felling suitability score for each individual based on the activity, health condition, and surrounding relative illuminance, and determines the individuals to be felled in descending order of the felling suitability score.

[0072] In a case in which the activity is less than a predetermined threshold value and a possibility of witheredness is high, the felling suitability score is high. In addition, when there is a defect of the trunk, the felling suitability score is high. This is because the defect is expected to reduce the future value of the timber. The increase in the score due to rot is greater than the increase in the score due to peeling of bark. In addition, the lower the surrounding relative illuminance, the higher the felling suitability score. This is because the density of trees of tree layer is high, resulting in insufficient irradiation of the trees of sub tree layer or bush layer with sunlight. In addition, the lower the height and the smaller the diameter, the higher the felling suitability score. Meanwhile, the lower the tree age, the lower the felling suitability score. That is, even when a tree is thin and low, the tree is not a felling target when the tree age thereof is low. The determination method of a felling target is not limited to this.

[0073] In another embodiment, the felling plan generation unit **723** may receive a designation of the number of trees to be felled instead of the felling rate. Additionally, the felling plan generation unit **723** may determine trees of which the felling suitability score exceeds the threshold value as felling targets without receiving the designation of the felling rate and the number of trees to be felled.

[0074] The felling instruction unit **724** generates an instruction signal that includes the traveling route, as well as the identification information of the tree to be felled and information indicating the position of the tree, based on the felling plan generated by the felling plan generation unit **723**, and transmits this instruction signal to the forestry machine **50**. When the felling instruction unit **724** receives a notification of felling completion from the forestry machine **50** along with the ID of the tree, the felling instruction unit **724** rewrites the felling status of the tree associated with the ID in the database **751** to "felled."

<<Process of Forestry Management Device **70**>>

[0075] FIG. **7** is a flowchart showing an update process of tree information performed by the forestry management device **70** according to the first embodiment. The operator uses the controller C**1** to control the low-altitude observation equipment **10** and the high-altitude observation equipment **30** to collect data on the trees within the target range of the forest F. The low-altitude observation equipment **10** collects data at the measurement time when the measurement instruction signal is transmitted by the operator. The high-altitude observation equipment **30** collects data at regular time intervals. In a case in which the operation via the operator is terminated, the low-altitude observation equipment **10** and the high-altitude observation equipment **30** transmit the collected data to the forestry management device **70**.

[0076] The data acquisition unit **711** acquires measurement data from the low-altitude observation equipment **10** and from the high-altitude observation equipment **30** (step S**1**). Information indicating the measurement time is included in the measurement data. The forestry management device **70** selects one piece of measurement data collected by the low-altitude observation equipment **10** at each of the plurality of measurement times (step S**2**), and executes the following processes from step S**3** to step S**18** using the selected measurement data.

[0077] First, the position specifying unit **712** specifies the three-dimensional position of the lower end portion of the tree from the position and posture of the low-altitude observation equipment **10** which are indicated by the measurement data selected in step S**2**, as well as the distance map of the low-altitude observation equipment **10** (step S**3**). Next, the fallen tree determination unit **713** specifies the axial direction of the tree from the distance map of the low-altitude observation equipment **10** selected in step S**2**, and determines whether or not the angle formed by the axial direction and the horizontal plane is less than the fallen tree determination threshold value (step S**4**). The fallen tree determination unit **713** determines that the tree is a fallen tree when the angle

formed by the axial direction of the tree and the horizontal plane is less than the fallen tree determination threshold value. In a case in which the fallen tree determination unit **713** determines that the tree is a fallen tree (step S**4**: YES), the forestry management device **70** skips monitoring of the condition of the tree and performs the process for the next measurement time in step S**2**. The fallen tree determination unit **713** may record the position at which the tree determined to be a fallen tree exists in the database **751**.

[0078] In a case in which the angle formed by the axial direction of the tree and the horizontal plane is equal to or greater than the fallen tree determination threshold value (step S**4**: NO), the fallen tree determination unit **713** determines that the tree is a living tree. Next, the identification unit **714** specifies the individual that is closest to the latitude and longitude of the tree specified in step S**3** and that is not felled from the database **751**, and determines whether or not the distance to the individual is less than a predetermined error threshold value (step S**5**). In a case in which the distance to the closest individual is less than the error threshold value (step S**5**: YES), the identification unit **714** determines that the tree shown in the distance map is the individual, and acquires the ID of the individual (step S**6**). On the other hand, in a case in which the distance to the closest individual is equal to or greater than the error threshold value (step S**5**: NO), the identification unit **714** determines that the tree shown in the distance map is a new individual, assigns a new ID to the tree (step S**7**), and records the three-dimensional position specified in step S**3** and the ID in association with each other in the database **751** (step S**8**).

[0079] In a case in which the identification unit **714** acquires the ID of the individual in step S**6** or in step S**7**, the treetop altitude calculation unit **715** specifies the altitude of the treetop of the individual specified in step S**6** or in step S**7** from the distance map of the high-altitude observation equipment **30** acquired in step S**1** (step S**10**).

[0080] The tree height calculation unit **716** calculates, as the height of the tree, the difference between the altitude of the ground surface calculated in step S**3** and the altitude of the treetop calculated in step S**10** (step S**11**). The diameter calculation unit **717** calculates the diameter of the tree from the distance image of the low-altitude observation equipment **10** (step S**12**). The species specifying unit **718** specifies the species of the tree based on the image captured by the imaging device **127** (step S**13**). The defect specifying unit **719** specifies the presence or absence of defect of trunk and the type of defect based on the image captured by the imaging device **127** (step S**14**). The activity calculation unit **720** specifies, from the data cube of the high-altitude observation equipment **30** where the plane position specified by the position specifying unit **712** is shown, a pixel corresponding to the plane position, and calculates the ratio of the brightness in the red region to the brightness in the infrared region of that pixel as the activity of the tree (step S**15**). The relative illuminance calculation unit **721** extracts the value corresponding to the time closest to the time at which the low-altitude observation equipment **10** measures the illuminance from the time series of the measurement value of the illuminance of the high-altitude observation equipment **30**, and calculates the relative illuminance using the illuminance of the low-altitude observation equipment **10** and the illuminance of the high-altitude observation equipment **30** (step S**16**).

[0081] The recording unit **722** records the obtained tree information, that is, the species specified in step S**13**, the height calculated in step S**11**, the diameter calculated in step S**12**, the activity calculated in step S**15**, the presence or absence of defect specified in step S**14**, and the surrounding relative illuminance calculated in step S**16**, in the database **751** in association with the ID acquired in step S**6** or in step S**7** and the measurement time (step S**17**).

[0082] By executing the above procedure for each measurement time of the low-altitude observation equipment **10**, the information related to the individual of tree in the database **751** can be updated to the latest information. The collection of tree information may be conducted at a time unrelated to thinning.

[0083] FIG. **8** is a flowchart showing a generation process of a felling plan performed by the forestry management device **70** according to the first embodiment. The operator accesses to the

forestry management device **70** at the execution time of thinning and inputs the target range of thinning and the felling rate. The felling rate may be automatically determined from an average value of the relative illuminances recorded in the database **751**, instead of being input by the operator.

[0084] The felling plan generation unit **723** receives the input of the target range and the felling rate from the user (step S**31**). The felling plan generation unit **723** determines the number of trees to be felled based on the number of trees that are not felled within the target range, which is recorded in the database **751**, and on the input felling rate (step S**32**). The felling plan generation unit **723** calculates the felling suitability score for each individual that is not felled within the target range, which is recorded in the database **751**, based on the latest condition of the individual (step S**33**). The felling plan generation unit **723** generates the felling plan by determining the individuals of trees to be felled of which the number is determined in step S**32** as felling targets in a descending order of felling suitability score (step S**34**).

[0085] The felling instruction unit **724** determines the traveling route of the forestry machine **50** based on the felling plan generated by the felling plan generation unit **723** (step S**35**). The felling instruction unit **724**, for example, searches for the shortest route that passes through all the individuals determined as felling targets. The felling instruction unit **724** generates an instruction signal that includes the determined traveling route, as well as the ID and position of the tree to be felled, and transmits this instruction signal to the forestry machine **50** (step S**36**). As a result, the forestry machine **50** autonomously travels along the traveling route and fells the trees to be felled. When the tree is felled, the control device **54** of the forestry machine **50** transmits a felling notification, which includes the ID of the felled individual, to the forestry management device **70**. In a case in which the felling instruction unit **724** receives the felling notification from the forestry machine **50** (step S**37**), the felling instruction unit **724** rewrites the felling status of the tree associated with the ID in the database **751** to "felled" (step S**38**).

[0086] As a result, the forestry management device **70** can cause the forestry machine **50** to execute felling based on the information on the trees collected by the low-altitude observation equipment **10** and by the high-altitude observation equipment **30**, and can record the felling results in the database **751**.

<<Action and Effect>>

[0087] As described above, with the forestry management system **1** according to the first embodiment, the position of the tree is specified based on the image captured by the low-altitude observation equipment **10** that moves through the forest at an altitude lower than the canopy and on the position at the time of capturing, and the individual of tree is identified based on this position. As a result, the forestry management system **1** can measure and manage all the trees in the forest, including those with treetops lower than the canopy, which cannot be measured by the high-altitude observation equipment **30**. Additionally, the forestry management system **1** records the tree information of the portion of each individual lower than the crown in the database **751** in association with the ID of the individual, based on the images captured by the low-altitude observation equipment **10**. As a result, the forestry management system **1** can collect the tree information of the portion lower than the crown, which is not shown in the image captured from the sky.

[0088] In addition, the forestry management system **1** according to the first embodiment can calculate the altitude of the ground surface on which the tree stands, which cannot be measured from the image captured from the sky, based on the image captured by the low-altitude observation equipment **10**. Based on the altitude of the ground surface and on the altitude of the treetop obtained from the image captured by the high-altitude observation equipment **30**, the forestry management system **1** can accurately obtain the height of the tree. In another embodiment, the forestry management system **1** is not limited to this, and may record the altitude of ground surface and the altitude of treetop in the database **751** and need not calculate the height of the tree. In

addition, the forestry management system **1** according to another embodiment need not record the information related to the height of the tree in the database **751**. That is, the forestry management system **1** according to another embodiment may record the data measured by only the low-altitude observation equipment **10** in the database **751**.

[0089] In addition, the forestry management system **1** according to the first embodiment calculates the relative illuminance based on the illuminance measured by the low-altitude observation equipment **10** and on the illuminance measured by the high-altitude observation equipment **30**, and records the relative illuminance in the database **751** in association with the individual of tree. The relative illuminance affects the growth of the bush layer and forest floor in the forest. Therefore, the forestry management system **1** can manage the forest F as appropriate by recording such information in the database **751**. The forestry management system **1** according to the first embodiment obtains the relative illuminance, but the present disclosure is not limited to this. In another embodiment, the forestry management system **1** may record the illuminance at an altitude lower than the canopy, that is, the illuminance measured by the low-altitude observation equipment **10**, in the database **751**. In this case, the high-altitude observation equipment **30** need not include the illuminance sensor **315**.

Second Embodiment

[0090] The low-altitude observation equipment **10** and the high-altitude observation equipment **30** according to the first embodiment are remotely operated by the operator. On the other hand, the low-altitude observation equipment **10** and the high-altitude observation equipment **30** according to the second embodiment are autonomously driven in accordance with instructions from the forestry management device **70**.

[0091] FIG. **9** is a schematic block diagram showing a configuration of the forestry management device **70** according to a second embodiment.

[0092] The forestry management device **70** according to the second embodiment further includes a measurement instruction unit **725** in addition to the configuration of the first embodiment.

[0093] The measurement instruction unit **725** generates an observation instruction signal that issues the instruction for observation of the trees existing in the target range of the forest F, and transmits the observation instruction signal to the low-altitude observation equipment **10** and to the high-altitude observation equipment **30**. The observation instruction signal includes information indicating the moving route. The measurement instruction unit **725** generates the moving route, for example, such that the trajectory of the measurement range of the distance measurement device **121** in accordance with the movement of the low-altitude observation equipment **10** covers the target range. In a case in which the route along which the forestry machine **50** is to travel is determined in advance, the measurement instruction unit **725** may transmit an observation instruction signal that sets the route along which the forestry machine **50** is to travel as the moving route. In addition, in a case in which the control device **126** of the low-altitude observation equipment **10** autonomously determines whether or not the target range is covered by the travel, the measurement instruction unit **725** may transmit the observation instruction signal including information indicating the target range instead of the moving route.

[0094] The control device **126** of the low-altitude observation equipment **10** causes the low-altitude observation equipment **10** to travel along the moving route indicated by the received observation instruction signal. For example, the control device **126** may generate an environment map using a simultaneous localization and mapping (SLAM) process based on the distance map captured by the distance measurement device **121** and on the position data measured by the position measurement device **122**, and may control the undercarriage **11** while modifying the moving route. During movement based on the observation instruction signal, the control device **126** determines whether or not a tree is shown in the distance map, and collects measurement data when the control device **126** determines that the tree is shown in the distance map. For example, the control device **126** can determine whether or not the tree is shown by using three-dimensional pattern matching, a learned

object detection model, or the like.

[0095] The control device **317** of the high-altitude observation equipment **30** causes the high-altitude observation equipment **30** to fly at a predetermined altitude higher than the canopy along the moving route indicated by the received observation instruction signal. The control device **317** may move the high-altitude observation equipment **30** in synchronization with the low-altitude observation equipment **10**, or may move the high-altitude observation equipment **30** independently of the low-altitude observation equipment **10**.

[0096] The control device **126** of the low-altitude observation equipment **10** and the control device **317** of the high-altitude observation equipment **30** may control the movement based on the instruction signal received from the operator when an interrupt operation is performed by the operator during autonomous driving. After that, when the instruction signal from the operator ceases, the control device **126** of the low-altitude observation equipment **10** and the control device **317** of the high-altitude observation equipment **30** switch to autonomous driving along the moving route.

[0097] When the movement along the moving route is completed, the control device **126** of the low-altitude observation equipment **10** and the control device **317** of the high-altitude observation equipment **30** transmit the collected measurement data to the forestry management device **70**.

[0098] As a result, the forestry management device **70** can record the tree information of the trees standing in the vicinity of the moving route in the database **751**.

Another Embodiment

[0099] Although the embodiments have been described in detail with reference to the drawings, a specific configuration is not limited to the above-described configuration, and various design changes and the like can be made. That is, in another embodiment, an order of the above-described processes may be changed as appropriate. In addition, some processes may be executed in parallel.

[0100] In the forestry management system **1** according to the above-described embodiment, the low-altitude observation equipment **10** and the high-altitude observation equipment **30** transmit the measurement data to the forestry management device **70** without processing the measurement data, and the forestry management device **70** calculates the tree information such as the species of tree, altitude of the ground surface, diameter, activity, and defect from the measurement data, but the present disclosure is not limited to this. For example, the forestry management system **1** according to another embodiment may be configured such that the control device **126** of the low-altitude observation equipment **10** or the control device **317** of the high-altitude observation equipment **30** calculates the tree information based on the measurement data, and the forestry management device **70** receives the calculated tree information. That is, the forestry management device **70** may be configured by a single computer, or may be configured by dividing the configuration of the forestry management device **70** and disposing the divided configurations in a plurality of computers, and the plurality of computers may function as the forestry management device **70** by cooperating with each other. In this case, some of the computers constituting the forestry management device **70** may be mounted inside the low-altitude observation equipment **10** or the high-altitude observation equipment **30**, and the other computers may be provided outside.

[0101] The forestry management system **1** according to the above-described embodiment generates the felling plan based on the information recorded in the database **751** and transmits the instruction to the forestry machine **50** which is autonomously driven, but the present disclosure is not limited to this. For example, the forestry management system **1** according to another embodiment may only manage the individual of tree without generating the felling plan. In addition, for example, in another embodiment, the forestry machine **50** may be operated directly by the operator or may be operated remotely without being autonomously driven. In this case, the forestry management device **70** outputs an instruction signal to instruct the operator to perform felling in accordance with the felling plan. This instruction signal may be a signal for displaying the felling plan on the monitor in the cab of the forestry machine **50**, or may be a signal for displaying the felling plan on

the portable terminal possessed by the operator.

[0102] The forestry management system **1** according to the above-described embodiment obtains the altitude of the ground surface on which the tree stands based on the measurement data from the low-altitude observation equipment **10**, and calculates the height of the tree based on this altitude, but the present disclosure is not limited to this. For example, the altitude of the ground surface may be read out from three-dimensional map data stored in the external database. In addition, the forestry management system **1** according to the above-described embodiment obtains the illuminance of sky via the illuminance sensor **315** provided in the high-altitude observation equipment **30**, and calculates the relative illuminance based on this illuminance, but the present disclosure is not limited to this. For example, the illuminance of sky may be read out from weather data or the like stored in the external database.

[0103] The forestry management system **1** according to the above-described embodiment includes the distance measurement device **121** that enables the low-altitude observation equipment **10** to acquire the distance map, in order to obtain condition quantities related to the size, such as the height and diameter, as the condition quantities of tree. On the other hand, in another embodiment, when only condition quantities unrelated to size, such as the species of tree or the presence or absence of defect, are calculated, the forestry management system **1** need not include the distance measurement device **121** for generating the distance map. In this case, the low-altitude observation equipment **10** may measure the distance to the tree by including a laser range finder or the like separately from the imaging device **127**.

Supplementary Note 1

[0104] A forestry management system including: a data acquisition unit configured to acquire a low-altitude distance map generated by a distance measurement device that generates a distance map and a position of the low-altitude observation equipment from the low-altitude observation equipment, the low-altitude observation equipment moving in a region of a forest near a ground surface where there are no branches and including the distance measurement device and a position measurement device that measures the position of the low-altitude observation equipment; a position specifying unit configured to specify a position of a tree, based on a distance from the low-altitude observation equipment to the tree specified based on the low-altitude distance map, and on the position of the low-altitude observation equipment; an identification unit configured to acquire identification information for identifying an individual of the tree based on the position of the tree; and a recording unit configured to record low-altitude tree information, which is tree information of a portion of the individual lower than branches that is measured based on the low-altitude distance map, in a database in association with the identification information.

Supplementary Note 2

[0105] The forestry management system according to Supplementary Note 1, further including: an altitude calculation unit configured to calculate an altitude of a ground surface on which the tree stands, which is the low-altitude tree information, based on the low-altitude distance map and on a three-dimensional position of the low-altitude observation equipment in a global coordinate system.

Supplementary Note 3

[0106] The forestry management system according to Supplementary Note 1 or 2, in which the recording unit records high-altitude tree information, which is tree information of the individual measured from a portion of high-altitude captured data captured from a sky of the forest at which the individual is shown, in the database in association with the identification information of the individual.

Supplementary Note 4

[0107] The forestry management system according to any one of Supplementary Notes 1 to 3, further including: a height calculation unit configured to calculate a height of the individual based on an altitude of a treetop of the individual measured from a portion of a high-altitude distance map

measured from an altitude higher than a canopy of the forest at which the individual is shown and on an altitude of a ground surface on which the individual stands, in which the recording unit records the height of the individual in the database in association with the identification information of the individual.

Supplementary Note 5

[0108] The forestry management system according to Supplementary Note 4, in which the height calculation unit specifies an altitude of a treetop of which a plane position is closest to a plane position of the individual related to the identification information, among a plurality of treetops specified from a high-altitude distance map measured from a sky of the forest, as the altitude of the treetop of the individual.

Supplementary Note 6

[0109] The forestry management system according to any one of Supplementary Notes 1 to 5, in which the low-altitude observation equipment includes an illuminance sensor, the data acquisition unit acquires illuminance data measured by the illuminance sensor, and the recording unit records a value related to the illuminance data in the database in association with the identification information of the tree.

Supplementary Note 7

[0110] The forestry management system according to any one of Supplementary Notes 1 to 6, in which the database stores the identification information for identifying the individual of the tree, a position of the individual, and the low-altitude tree information of the individual in association with each other, and the identification unit provides new identification information to the individual in a case in which identification information corresponding to the specified position is not recorded in the database.

Supplementary Note 8

[0111] The forestry management system according to any one of Supplementary Notes 1 to 7, in which the low-altitude observation equipment moves through the forest along a traveling route along which a forestry machine that fells the tree travels, and the recording unit records low-altitude tree information of a tree standing in a vicinity of the traveling route in the database.

Supplementary Note 9

[0112] The forestry management system according to any one of Supplementary Notes 1 to 8, further including: a felling plan generation unit configured to generate a felling plan indicating an individual to be felled by a forestry machine that fells the tree, based on information recorded in the database; and a felling instruction unit configured to transmit an instruction signal that instructs the forestry machine to perform felling according to the generated felling plan.

Supplementary Note 10

[0113] The forestry management system according to any one of Supplementary Notes 1 to 9, further including: a fallen tree determination unit configured to determine whether the tree shown in the low-altitude captured data is a fallen tree or a living tree based on an angle of the tree with respect to horizontal, in which the identification unit acquires the identification information of the tree in a case in which the tree is determined to be the living tree.

INDUSTRIAL APPLICABILITY

[0114] According to the above aspect, a forestry management system can manage conditions of trees forming a forest.

REFERENCE SIGNS LIST

[0115] **1**: Forestry management system [0116] **10**: Low-altitude observation equipment [0117] **11**: Undercarriage [0118] **12**: Fuselage [0119] **121**: Distance measurement device [0120] **122**: Position measurement device [0121] **123**: Posture measurement device [0122] **124**: Illuminance sensor [0123] **125**: Battery [0124] **126**: Control device [0125] **127**: Imaging device [0126] **30**: High-altitude observation equipment [0127] **31**: Fuselage [0128] **311**: Distance measurement device [0129] **312**: Multispectral camera [0130] **313**: Position measurement device [0131] **314**: Posture

measurement device [0132] **315**: Illuminance sensor [0133] **316**: Battery [0134] **317**: Control device [0135] **32**: Propeller [0136] **50**: Forestry machine [0137] **51**: Vehicle body [0138] **511**: Position measurement device [0139] **52**: Undercarriage [0140] **53**: Work equipment [0141] **531**: Boom [0142] **532**: Arm [0143] **533**: Head [0144] **5331**: Grapple [0145] **5332**: Circular saw [0146] **534**: Arm cylinder [0147] **535**: Head cylinder [0148] **54**: Control device [0149] **70**: Forestry management device [0150] **71**: Processor [0151] **751**: Database [0152] **711**: Data acquisition unit [0153] **712**: Position specifying unit [0154] **713**: Fallen tree determination unit [0155] **714**: Identification unit [0156] **715**: Treetop altitude calculation unit [0157] **716**: Tree height calculation unit [0158] **717**: Diameter calculation unit [0159] **718**: Species specifying unit [0160] **719**: Defect specifying unit [0161] **720**: Activity calculation unit [0162] **721**: Relative illuminance calculation unit [0163] **722**: Recording unit [0164] **723**: Felling plan generation unit [0165] **724**: Felling instruction unit [0166] **725**: Measurement instruction unit [0167] **73**: Main memory [0168] **75**: Storage [0169] **77**: Interface [0170] F: Forest [0171] N: Communication network

Claims

1. A forestry management system comprising: at least one memory storing instructions, and at least one processor configured to execute the instructions, wherein the at least one processor is further configured to: acquire a low-altitude distance map generated by a distance measurement device that generates a distance map and a position of low-altitude observation equipment from the low-altitude observation equipment, the low-altitude observation equipment moving in a region of a forest near a ground surface where there are no branches and including the distance measurement device and a position measurement device that measures the position of the low-altitude observation equipment; specify a position of a tree, based on a distance from the low-altitude observation equipment to the tree specified based on the low-altitude distance map, and on the position of the low-altitude observation equipment; acquire identification information for identifying an individual of the tree based on the position of the tree; and record low-altitude tree information, which is tree information of a portion of the individual lower than branches that is measured based on the low-altitude distance map, in a database in association with the identification information.
2. The forestry management system according to claim 1, wherein the at least one processor is further configured to: calculate an altitude of a ground surface on which the tree stands, which is the low-altitude tree information, based on the low-altitude distance map and on a three-dimensional position of the low-altitude observation equipment in a global coordinate system.
3. The forestry management system according to claim 1, wherein the at least one processor is further configured to: record high-altitude tree information, which is tree information of the individual measured from a portion of high-altitude captured data captured from a sky of the forest at which the individual is shown, in the database in association with the identification information of the individual.
4. The forestry management system according to claim 1, wherein the at least one processor is further configured to: calculate a height of the individual based on an altitude of a treetop of the individual measured from a portion of a high-altitude distance map measured from an altitude higher than a canopy of the forest at which the individual is shown and on an altitude of a ground surface on which the individual stands, wherein the recording unit records the height of the individual in the database in association with the identification information of the individual.
5. The forestry management system according to claim 4, wherein the at least one processor is further configured to: specify an altitude of a treetop of which a plane position is closest to a plane position of the individual related to the identification information, among a plurality of treetops specified from a high-altitude distance map measured from a sky of the forest, as the altitude of the treetop of the individual.

6. The forestry management system according to claim 1, wherein the low-altitude observation equipment includes an illuminance sensor, and the at least one processor is further configured to: acquire illuminance data measured by the illuminance sensor, and record a value related to the illuminance data in the database in association with the identification information of the tree.

7. The forestry management system according to claim 1, wherein the database stores the identification information for identifying the individual of the tree, a position of the individual, and the low-altitude tree information of the individual in association with each other, and the at least one processor is further configured to: provide new identification information to the individual in a case in which identification information corresponding to the specified position is not recorded in the database.

8. The forestry management system according to claim 1, wherein the low-altitude observation equipment moves through the forest along a traveling route along which a forestry machine that fells the tree travels, and the at least one processor is further configured to: record low-altitude tree information of a tree standing in a vicinity of the traveling route in the database.

9. The forestry management system according to claim 1, wherein the at least one processor is further configured to: generate a felling plan indicating an individual to be felled by a forestry machine that fells the tree, based on information recorded in the database; and transmit an instruction signal that instructs the forestry machine to perform felling according to the generated felling plan.

10. The forestry management system according to claim 1, wherein the at least one processor is further configured to: determine whether the tree shown in low-altitude captured data captured by the low-altitude observation equipment is a fallen tree or a living tree based on an angle of the tree with respect to horizontal; and acquire the identification information of the tree in a case in which the tree is determined to be the living tree.

11. A forestry management method comprising: a step of acquiring a low-altitude distance map generated by a distance measurement device that generates a distance map and a position of low-altitude observation equipment from the low-altitude observation equipment, the low-altitude observation equipment moving in a region of a forest near a ground surface where there are no branches and including the distance measurement device and a position measurement device that measures the position of the low-altitude observation equipment; a step of specifying a position of a tree, based on a distance from the low-altitude observation equipment to the tree specified based on the low-altitude distance map, and on the position of the low-altitude observation equipment; a step of acquiring identification information for identifying an individual of the tree based on the position of the tree; and a step of recording low-altitude tree information, which is tree information of a portion of the individual lower than branches that is measured based on the low-altitude distance map, in a database in association with the identification information.