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Control system of working machine and control method of working machine

Abstract

To provide a control system of a working machine and a control method of the working machine that enables an operator side to control the working machine, on the basis of an image transmitted from the working machine side. In a control system of a working machine which operates the working machine by an image from the working machine side, the working machine includes an image processing unit which converts a color image into a grayscale image; and a working machine communication unit which transmits the grayscale image from the working machine side to the system side, and the system includes a system communication unit which receives the grayscale image transmitted by the working machine; and a processing unit which restores a color image from the grayscale image, by the use of a learning model created using an original image of a working area, and an image in which tonal information is reduced from the original image.

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Patent No.	Application Date	Country	CPC
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Background/Summary

BACKGROUND OF THE INVENTION
Field of the Invention
(1) The present invention relates to a control system of a working machine and a control method of a working machine.
Description of Related Art
(2) There is a case in which a delivery robot may be remotely controlled via a human intervention in a situation in which it is difficult to make determinations during automatic driving. One situation in which it is difficult to make determinations is, for example, passing through an intersection, or the like. An operator at a remote location performs remote control, while viewing an image from a camera mounted on the delivery robot. When there is a delay in transmission of an image, the operator cannot accurately determine the situation at the site. Therefore, it is necessary to transmit images with as little delay as possible. In order to transmit images with little delay, it is possible to reduce the data capacity of images as much as possible.
(3) Regarding techniques for reducing the data capacity of communication, a technique for reducing the resolution of regions other than a region of interest is known (for example, see Patent Document 1). This technique selects one piece of image data from a plurality of pieces of image data as main image data, selects sub-image data from image data other than the image data selected

as the main image data, reduces and converts the selected sub-image data into image data having a resolution smaller than that of the main image data, and creates display data in which the converted sub-image data is disposed superimposed inside the main image data. [Patent Document 1] Japanese Unexamined Patent Application, First Publication No. 2010-114575

SUMMARY OF THE INVENTION

(4) An object of the present invention is to provide a control system of a working machine and a control method of the working machine that can control the working machine on an operator side, on the basis of an image transmitted from the working machine side.

(5) The control system of the working machine according to the present invention has the following configuration. (1): A control system of a working machine according to an aspect of the present invention is a control system of a working machine which operates the working machine by an image from the working machine side, in which the working machine includes an image processing unit which converts a color image into a grayscale image, and a working machine communication unit which transmits the grayscale image from the working machine side to the system side, and the system includes a system communication unit which receives the grayscale image transmitted by the working machine, and a processing unit which restores a color image from the grayscale image, by the use of a learning model created using an original image of a working area and an image in which tonal information of the original image is reduced. (2): In the above aspect (1), the image processing unit creates an image obtained by lowering the resolution of the grayscale image, the working machine communication unit transmits the image obtained by lowering the resolution of the grayscale image from the working machine side to the system side, the system communication unit receives the image obtained by lowering the resolution of the grayscale image transmitted by the working machine, and the processing unit restores a color image from the image obtained by lowering the resolution of the grayscale image, by the use of the learning model created using the original image of the working area and the image obtained by lowering the resolution of the image in which tonal information is reduced from the original image. (3): In the above aspect (1), the working machine includes a relearning determination unit which determines whether to relearn the learning model on the basis of a plurality of object regions included in the color image acquired at a plurality of time points. (4): In the above aspect (3), the relearning determination unit acquires a difference portion from a difference image between images obtained by dividing a plurality of objects included in the color image acquired at a plurality of time points into respective objects and determines whether to relearn the learning model on the basis of the number of pixels of the acquired difference portion. (5): In the above aspect (4), the relearning determination unit determines to relearn the learning model, when the number of pixels of the difference portion is equal to or greater than a threshold value.

(6) The control method of the working machine according to the present invention adopts the following configuration. (6): A control method of a working machine which operates the working machine by an image from the working machine side, in which the working machine converts a color image into a grayscale image, the working machine transmits the grayscale image from the working machine side to the system side, the system receives the grayscale image transmitted by the working machine, and the system restores a color image from the grayscale image, by the use of a learning model created using an original image of a working area, and an image in which tonal information is reduced from the original image.

(7) According to (1) to (6), it is possible to control the working machine on the operator side, on the basis of the image transmitted from the working machine side.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** is a diagram for explaining an example of a control system of a working machine according to the present embodiment.

(2) FIG. **2**A is a diagram for explaining an example of the operation of the control system of the working machine according to the present embodiment.

(3) FIG. **2**B is a diagram for explaining an example of the operation of the control system of the working machine according to the present embodiment.

(4) FIG. **2**C is a diagram for explaining an example of the operation of the control system of the working machine according to the present embodiment.

(5) FIG. **2**D is a diagram for explaining an example of the operation of the control system of the working machine according to the present embodiment.

(6) FIG. **3** is a flowchart showing an example of the operation of the working machine, a system, a learning device, and a cloud server according to the present embodiment.

(7) FIG. **4** is a flowchart showing an example of the operation of the working machine, the system and the cloud server according to the present embodiment.

(8) FIG. **5** is a diagram for explaining an example of the operation of the working machine according to a modified example of the embodiment.

(9) FIG. **6** is a diagram showing an example of a working machine of a modified example of the embodiment.

(10) FIG. **7** is a diagram showing an example of a working area image information table.

(11) FIG. **8** is a flowchart showing an example of the operation of the working machine, the system, the learning device, and the cloud server according to the modified example of the embodiment.

DETAILED DESCRIPTION OF THE INVENTION

(12) Next, a control system of a working machine and a control method of the working machine according to the present embodiment will be described with reference to the drawings. The embodiment to be described below is merely an example, and embodiments to which the present invention is applied are not limited to the following embodiment. In addition, in all the drawings for explaining the embodiment, the same reference numerals are used for the parts having the same functions, and repeated explanations will not be provided.

(13) In addition, "on the basis of XX" in the present application means "at least based on XX" and includes a case of being based on another element in addition to XX. Moreover, "on the basis of XX" is not limited to a case of using XX directly, but also includes a case of being based on what has been calculated or processed with respect to XX. "XX" is an arbitrary element (for example, arbitrary information).

Embodiment

(14) Hereinafter, embodiments of the present invention will be described in detail with reference to the drawings. FIG. **1** is a diagram for explaining an example of a control system of a working machine according to the present embodiment. A control system **500** of the working machine includes a working machine **100**, a system **200**, a learning device **300**, and a cloud server CS. The working machine **100**, the system **200**, the learning device **300**, and the cloud server CS communicate with each other via a network NW. The network NW includes, for example, the Internet, a Wide Area Network (WAN), a local area network (LAN), a provider device, a radio base station, and the like.

(15) The working machine **100** is an autonomously traveling vehicle and travels along a route through navigation by the system **200**. Preparations before operation will be explained. The working machine **100** is made to travel in a working area such as a construction site where an operation is planned. For example, the working machine **100** is made to travel by wirelessly transmitting a movement command from the system **200** to the working machine **100**. The working

machine **100** is equipped with a camera, captures an image of the surroundings of the working machine **100** by the camera while traveling and saves a plurality of first original images of the working area obtained by capturing an image.

(16) The working machine **100** acquires a plurality of second images in which tonal information of the plurality of first images obtained by capturing an image has been reduced. For example, the working machine **100** converts a plurality of original color images of the working area into a plurality of grayscale images with reduced tonal information.

(17) The working machine **100** transmits a plurality of pieces of learning data, in which first image information of the first image is associated with second image information of the second image obtained by reducing the tonal information from the first image, to the cloud server CS. The cloud server CS receives a plurality of pieces of learning data transmitted by the working machine **100**. The cloud server CS stores a plurality of pieces of learning data.

(18) The learning device **300** acquires a plurality of pieces of learning data stored in the cloud server CS. The learning device **300** creates a learning model, by performing machine learning on a relationship between the colors included in the first image and the colors included in the second image, using the first image information and the second image information included in each of the acquired plurality of pieces of learning data. The learning device **300** creates a learning model notification including the created learning model. The learning device **300** transmits the created learning model notification to the system **200**.

(19) The system **200** receives the learning model notification transmitted from the learning device **300**. The system **200** acquires the learning model included in the received learning model notification and stores and sets the acquired learning model.

(20) FIGS. **2**A to **2**D are diagrams for explaining an example of the operation of the control system of the working machine according to the present embodiment. The working machine **100** travels along a route through navigation by the system **200**. For example, the working machine **100** travels along a route of the working area. As shown in FIG. **2**A, the working machine **100** captures an image of the surroundings of the working machine **100** in a situation in which determinations of autonomous travel are difficult. As shown in FIG. **2**B, the working machine **100** converts a color image obtained by capturing the image of the surroundings of the working machine **100** into a grayscale image.

(21) The working machine **100** transmits the image information of the grayscale image from the working machine side to the cloud server CS, as shown in (1) of FIG. **2**C. The cloud server CS receives the image information of the grayscale image transmitted by the working machine **100**. The cloud server CS temporarily stores the image information of the received grayscale image and transmits it to the system **200**.

(22) The system **200** includes a learning model created by performing a machine learning on a relationship between the colors included in the first images and the colors included in the second image, using a plurality of first original images of the working area and a plurality of second images in which tonal information is reduced from each of the plurality of first original images.

(23) The system **200** receives the image information of the grayscale image transmitted by the cloud server CS, as shown in (2) of FIG. **2**C. The system **200** inputs the image information of the received grayscale image to the learning model and acquires the image information of the color image that is output by the learning model. By configuring in this manner, the color image can be restored from the grayscale image. The system **200** displays the color image by obtaining the image information of the obtained color image.

(24) The operator of the working machine **100** remotely operates the working machine **100** by referring to the color image displayed on the system **200**, as shown in FIG. **2**D. The system **200** creates a movement command (control information) on the basis of operation of the operator and transmits the created movement command to the working machine **100**. The working machine **100** receives the movement command transmitted by the system **200** and operates on the basis of the

received movement command.

(25) Returning to FIG. **1**, the working machine **100**, the system **200**, and the learning device **300** according to the present embodiment will be described in detail.

(26) (Working Machine **100**)

(27) The working machine **100** includes a communication unit **102**, a sensor **103**, a determination unit **104**, an image capturing unit **105**, an image processing unit **106**, a creation unit **108**, a control unit **110**, a position estimation unit **112**, a drive device **140** and a storage unit **150**.

(28) The communication unit **102** is implemented by a communication module. The communication unit **102** communicates with an external communication device via the network NW. The communication unit **102** communicates, for example, in a wireless communication manner such as via a wireless LAN, Bluetooth (registered trademark) or LTE (registered trademark). The communication unit **102** holds communication information necessary for communicating with the system **200**, the learning device **300**, and the cloud server CS via the network NW.

(29) For example, the sensor **103** measures a distance to any object in a traveling direction of the working machine **100**. The sensor **103** is configured to have, for example, Light Detection And Ranging (LiDAR). LiDAR measures a three-dimensional distance to an object to be measured, and extracts point cloud data from the measured three-dimensional distance.

(30) The determination unit **104** acquires the point cloud data from the sensor **103** and determines whether the traveling direction of the working machine **100** is that of a situation in which determinations of autonomous travel are difficult, on the basis of the acquired point cloud data. An example of a situation in which it is difficult to determine the autonomous travel is a situation in which the working machine **100** is at an intersection. The determination unit **104** instructs the image capturing unit **105** to take an image when determining that it is difficult to determine the autonomous travel.

(31) The image capturing unit **105** acquires the color image information by capturing the image of the surroundings of the working machine **100**. In preparation before operation, the image capturing unit **105** acquires the image information of the first image by capturing the image of the surroundings of the working machine **100**, when the working machine **100** is traveling on the basis of a movement command from the system **200**. In addition, when an image capturing command is input by the determination unit **104** at the time of operation, the image capturing unit **105** acquires the image information of a color image by capturing the image of the surroundings such as those in the traveling direction of the working machine **100**. Here, the image information of the color image is image information of an image whose colors are represented by the three primary colors of light "red (R), green (G), and blue (B)".

(32) The image processing unit **106** acquires the image information of the color image from the image capturing unit **105** and converts the acquired image information of the color image into the image information of the grayscale image. Here, the image information of the grayscale image represents one pixel with 8 bits and does not include color information and includes only brightness information. This 8-bit image can express gradations up to 2 to the power of 8 (=256). A pixel value of 0 is black, and a pixel value of 255 is white. The image processing unit **106** acquires the image information of the first image from the image capturing unit **105** and converts the acquired image information of the first image into the image information of the second image in preparation before operation. The image processing unit **106** acquires the image information of a color image from the image capturing unit **105** at the time of operation and converts the acquired image information of the color image into the image information of the grayscale image.

(33) The creation unit **108** creates a plurality of pieces of learning data in which the image information of the first image and the image information of the second image are associated from the image processing unit **106**. The creation unit **108** transmits the created plurality of pieces of learning data from the communication unit **102** to the learning device **300**. The creation unit **108**

also acquires the grayscale image information from the image processing unit **106**. The creation unit **108** creates an image notification including the acquired grayscale image information and the identification information of the working machine **100** and transmits the created image notification from the communication unit **102** to the system **200**.

(34) The position estimation unit **112** estimates the position of the working machine **100**. For example, the position estimation unit **112** is configured to include a global navigation satellite system (GNSS), and performs a position measurement, using signals emitted from navigation satellites.

(35) The control unit **110** acquires the positional information of the working machine **100** from the position estimation unit **112** and controls the travel of the working machine **100** to pass through the route that is set by the system **200** on the basis of the acquired positional information. The control unit **110** controls the travel of the working machine **100**, by outputting a shaft speed of wheels and the like to the drive device **140** as a movement command.

(36) The storage unit **150** is implemented by a Hard Disk Drive (HDD), a flash memory, a Random Access Memory (RAM), a Read Only Memory (ROM), and the like, and stores information.

(37) The drive device **140** is made up of an actuator (not shown), an encoder and a control device thereof, and a movement mechanism having a plurality of combinations of wheels and steering shafts connected to the output shaft of the actuator. The movement mechanism is driven on the basis of a movement command from the control unit **110** and a movement command from the system **200**.

(38) The determination unit **104**, the image processing unit **106**, the creation unit **108**, the control unit **110**, and the position estimation unit **112** are implemented, for example, by executing a computer program (software) stored in the storage unit **150** by a hardware processor such as a Central Processing Unit (CPU).

(39) Also, some or all of these functional units may be implemented by hardware (a circuit unit including circuitry) such as a Large Scale Integration (LSI), an Application Specific Integrated Circuit (ASIC), a Field-Programmable Gate Array (FPGA), and a Graphics Processing Unit (GPU), or may be implemented by cooperation of software and hardware.

(40) The computer program may be stored in a storage device such as an HDD or a flash memory in advance or may be stored in a detachable storage medium such as a Digital Versatile Disc (DVD) or a CD-ROM, and may be installed by mounting the storage medium to the drive device.

(41) (System **200**)

(42) The system **200** is implemented by a device such as a personal computer, a server, a smart phone, a tablet computer or an industrial computer. The system **200** controls the travel of the working machine **100**. The system **200** includes a communication unit **202**, a processing unit **206**, an operation unit **207**, a creation unit **208**, a display unit **212**, and a storage unit **250**.

(43) The communication unit **202** is implemented by a communication module. The communication unit **202** communicates with an external communication device via the network NW. The communication unit **202** communicates, for example, in a wireless communication manner such as a wireless LAN, a Bluetooth (registered trademark) or a LTE (registered trademark). The communication unit **202** holds communication information necessary for communicating with the working machine **100**, the learning device **300**, and the cloud server CS via the network NW. The communication unit **202** receives the learning model notification transmitted by the learning device **300** and receives the image notification transmitted by the working machine **100**.

(44) The processing unit **206** acquires the learning model notification received by the communication unit **202** and acquires the learning model included in the acquired learning model notification. The processing unit **206** stores and sets the acquired learning model. As described above, the learning model is created by performing a machine learning a relationship between the colors included in the first image and the colors included in the second image, using a plurality of

first original images of the working area and a plurality of second images in which tonal information is reduced from each of the plurality of first original images.

(45) The processing unit **206** acquires the image notification from the communication unit **202** and acquires the image information of the grayscale image and the identification information of the working machine **100** included in the acquired image notification. The processing unit **206** inputs the acquired image information of the grayscale image to the learning model and acquires the image information of the color image that is output by the learning model. The processing unit **206** outputs the image information of the color image to the display unit **212**.

(46) The operation unit **207** is an input device that receives operation of the operator. Specifically, the operation unit **207** creates the travel control information when the operator operates the operation unit **207** to perform an operation of controlling the travel of the working machine **100**.

(47) The creation unit **208** acquires the travel control information from the operation unit **207** and creates a movement command on the basis of the acquired travel control information. The creation unit **208** transmits the created movement command from the communication unit **202** to the working machine **100**.

(48) The display unit **212** is configured to include, for example, a touch panel. The display unit **212** acquires the color image information that is output from the processing unit **206** and displays a screen that accepts the operation for controlling the travel of the working machine **100** by the operator on the basis of the acquired color image information.

(49) The storage unit **250** is implemented by an HDD, a flash memory, a RAM, a ROM, and the like, and stores information.

(50) The processing unit **206**, the operation unit **207**, and the creation unit **208** are implemented by, for example, executing a computer program (software) stored in the storage unit **250** by a hardware processor such as a CPU.

(51) Also, some or all of these functional units may be implemented by hardware (circuit unit including circuitry) such as an LSI, an ASIC, a FPGA, and a GPU, or may be implemented by cooperation of software and hardware.

(52) The computer program may be stored in a storage device such as an HDD or a flash memory in advance or may be stored in a detachable storage medium such as a DVD or CD-ROM, and may be installed by mounting the storage medium to the drive device.

(53) (Learning Device **300**)

(54) The learning device **300** is implemented by a device such as a personal computer, a server, a smart phone, a tablet computer or an industrial computer. The learning device **300** creates a learning model. The learning device **300** includes a communication unit **302**, a processing unit **306**, a creation unit **308** and a storage unit **350**.

(55) The communication unit **302** is implemented by a communication module. The communication unit **302** communicates with an external communication device via the network NW. The communication unit **302** communicates, for example, in a wireless communication manner such as a wireless LAN, a Bluetooth (registered trademark) or an LTE (registered trademark). The communication unit **302** holds communication information necessary for communicating with the working machine **100**, the system **200**, and the cloud server CS via the network NW. The communication unit **302** receives the learning data transmitted by the cloud server CS and transmits the learning model notification created by the creation unit **308** to the system **200**.

(56) The processing unit **306** acquires a plurality of pieces of learning data received by the communication unit **302**. The processing unit **306** acquires a combination of the image information of the first image and the image information of the second image included in each of the plurality of pieces of acquired learning data. The processing unit **306** creates a learning model, by performing machine learning on the relationship between the colors included in the first image and the colors included in the second image, using the combination of the acquired image information

of the first image and the acquired image information of the second image. For example, the processing unit **306** creates a learning model, using algorithms used in unsupervised learning such as generative adversarial networks (GAN).

(57) The creation unit **308** acquires the learning model from the processing unit **306**. The creation unit **308** creates a learning model notification including the acquired learning model. The creation unit **308** outputs the created learning model notification to the communication unit **302**.

(58) The communication unit **302** transmits the learning model notification, which is output by the creation unit **308**, to the system **200**.

(59) The storage unit **350** is implemented by an HDD, a flash memory, a RAM, a ROM, and the like, and stores information.

(60) The processing unit **306** and the creation unit **308** are implemented, for example, by executing a computer program (software) stored in the storage unit **350** by a hardware processor such as a CPU.

(61) Also, some or all of these functional units may be implemented by hardware (circuit unit including circuitry) such as an LSI, an ASIC, a FPGA and a GPU, or may be implemented by cooperation of software and hardware.

(62) The computer program may be stored in a storage device such as an HDD or a flash memory in advance or may be stored in a detachable storage medium such as a DVD or a CD-ROM, and may be installed by mounting the storage medium to a drive device.

(63) (Operations of Working Machine **100**, System **200**, and Learning Device **300**)

(64) FIG. **3** is a flow chart showing an example of the operation of the working machine, the system, the learning device, and the cloud server according to the present embodiment. Preparations before operation will be described with reference to FIG. **3**.

(65) (Step S**1-1**)

(66) The working machine **100** travels along a route of a working area such as a construction site in which the operation is scheduled.

(67) (Step S**2-1**)

(68) In the working machine **100**, the image capturing unit **105** acquires image information of the first image by capturing the image of the surroundings of the working machine **100**.

(69) (Step S**3-1**)

(70) In the working machine **100**, the image processing unit **106** acquires the image information of the first image from the image capturing unit **105**. The image processing unit **106** converts the acquired image information of the first image into image information of the second image.

(71) (Step S**4-1**)

(72) In the working machine **100**, the creation unit **108** creates a plurality of pieces of learning data in which the image information of the first image and the image information of the second image are associated from the image processing unit **106**.

(73) (Step S**5-1**)

(74) In the working machine **100**, the creation unit **108** transmits the created plurality of pieces of learning data from the communication unit **102** to the cloud server CS.

(75) (Step S**6-1**)

(76) The cloud server CS receives a plurality of pieces of learning data transmitted by the working machine **100** and stores the received plurality of pieces of learning data.

(77) (Step S**7-1**)

(78) The cloud server CS transmits a plurality of pieces of learning data to the learning device **300**.

(79) (Step S**8-1**)

(80) In the learning device **300**, the communication unit **302** receives a plurality of pieces of learning data transmitted by the cloud server CS. The processing unit **306** acquires a plurality of pieces of learning data received by the communication unit **302**. The processing unit **306** acquires a combination of the image information of the first image and the image information of the second

image included in each of the plurality of pieces of acquired learning data. The processing unit **306** creates a learning model, by performing machine learning on the relationship between the colors included in the first image and the colors included in the second image, using a combination of the acquired image information of the first image and the acquired image information of the second image.

(81) (Step S**9-1**)

(82) In the learning device **300**, the creation unit **308** acquires the learning model from the processing unit **306**. The creation unit **308** creates a learning model notification including the acquired learning model.

(83) (Step S**10-1**)

(84) In the learning device **300**, the creation unit **308** transmits the created learning model notification from the communication unit **302** to the system **200**.

(85) (Step S**11-1**)

(86) In the system **200**, the communication unit **202** receives the learning model notification transmitted by the learning device **300**. The processing unit **206** acquires the learning model notification received by the communication unit **202** and acquires the learning model included in the acquired learning model notification. The processing unit **206** stores and sets the acquired learning model.

(87) FIG. **4** is a flowchart showing an example of the operation of the working machine, the system, and the cloud server according to the present embodiment. Operation at the time of operation will be described with reference to FIG. **4**.

(88) (Step S**1-2**)

(89) The working machine **100** travels along a route through navigation by the system **200**. The sensor **103** measures a three-dimensional distance to an object to be measured, and extracts point cloud data from the measured three-dimensional distance.

(90) (Step S**2-2**)

(91) In the working machine **100**, the determination unit **104** acquires the point cloud data from the sensor **103** and determines whether the traveling direction of the working machine **100** is in a situation in which determination of the autonomous travel is difficult, on the basis of the acquired point cloud data. If the determination unit **104** determines that the traveling direction of the working machine **100** is not in a situation in which determination of autonomous travel is difficult, the process returns to step S**1-2**.

(92) (Step S**3-2**)

(93) In the working machine **100**, the determination unit **104** commands the image capturing unit **105** to capture an image when it is determined that there is a situation in which determination of the autonomous travel is difficult. The image capturing unit **105** acquires color image information by capturing the image of the surroundings of working machine **100**, when the determination unit **104** inputs an image capturing command.

(94) (Step S**4-2**)

(95) In the working machine **100**, the image processing unit **106** acquires image information of a color image from the image capturing unit **105**. The image processing unit **106** converts the acquired image information of a color image into image information of a grayscale image.

(96) (Step S**5-2**)

(97) In the working machine **100**, the creation unit **108** acquires the image information of a grayscale image from the image processing unit **106**. The creation unit **108** creates an image notification including the image information of the acquired grayscale image and the identification information of the working machine **100**.

(98) (Step S**6-2**)

(99) In the working machine **100**, the creation unit **108** transmits the created image notification from the communication unit **102** to the cloud server CS.

(100) (Step S**7-2**)

(101) The cloud server CS receives the image notification transmitted by the working machine **100** and stores the received image notification.

(102) (Step S**8-2**)

(103) The cloud server CS transmits the image notification to the system **200**.

(104) (Step S**9-2**)

(105) In the system **200**, the communication unit **202** receives the image notification transmitted by the cloud server CS. The processing unit **206** acquires the image notification from the communication unit **202** and acquires the image information of the grayscale image and the identification information of the working machine **100** included in the acquired image notification. The processing unit **206** inputs the acquired image information of the grayscale image to the learning model and acquires the image information of the color image that is output by the learning model.

(106) (Step S**10-2**)

(107) In the system **200**, the processing unit **206** outputs the acquired image information of the color image to the display unit **212**. The display unit **212** acquires the image information of the color image that is output by the processing unit **206** and displays a screen that accepts an operation for controlling the travel of the working machine **100** by the operator on the basis of the acquired image information of the color image.

(108) (Step S**11-2**)

(109) In the system **200**, the operation unit **207** creates travel control information when the operator operates the operation unit **207** to perform an operation for controlling the travel of the working machine **100**.

(110) (Step S**12-2**)

(111) In the system **200**, the creation unit **208** acquires travel control information from the operation unit **207** and creates a movement command on the basis of the acquired travel control information.

(112) (Step S**13-2**)

(113) In the system **200**, the creation unit **208** transmits the created movement command from the communication unit **202** to the working machine **100**.

(114) (Step S**14-2**)

(115) In the working machine **100**, the communication unit **102** receives the movement command transmitted by the system **200**. The movement mechanism acquires a movement command from the communication unit **102** and drives on the basis of the acquired movement command.

(116) In the above-described embodiment, although a case in which the learning data is acquired by learning device **300** from the working machine **100** via the cloud server CS, and the image notification is acquired by the system **200** from the working machine **100** via the cloud server CS has been described as an example, the present invention is not limited to this example. For example, a configuration in which the learning data is acquired by the learning device **300** from the working machine **100** without going through the cloud server CS, and the image notification is acquired by the system **200** from the working machine **100** without going through the cloud server CS may be adopted.

(117) In the above-described embodiment, although a case in which the determination unit **104** acquires the point cloud data from the sensor **103** and determines whether the traveling direction of the working machine **100** is in a situation in which determination of the autonomous travel is difficult, on the basis of the acquired point cloud data has been described as an example, the present invention is not limited to this example. For example, the determination unit **104** may acquire an image of the traveling direction of the working machine **100** from the image capturing unit **105** and may determine whether the traveling direction of the working machine **100** is in a situation in which determination of the autonomous travel is difficult, on the basis of the acquired

image.

(118) In the above-described embodiment, although a case in which the working machine **100** converts a color image into a grayscale image and transmits the grayscale image from the working machine **100** to the system **200** has been described, the present invention is not limited to this example. For example, the working machine **100** may create an image obtained by lowering a resolution of the grayscale image and may transmit the image obtained by lowering the resolution of the grayscale image from the working machine **100** to the system **200**. In this case, the system **200** restores a color image from the image obtained by lowering the resolution of the grayscale image, by the use of a learning model which is created using the original image of the working area, and the image obtained by lowering the resolution of the image in which the tonal information is reduced from the original image.

(119) Because the size of the image transmitted from the working machine **100** to the system **200** can be further reduced, compared to a case where the grayscale image is transmitted from the working machine **100** by such a configuration, even lower delay can be achieved.

(120) According to the control system **500** of the working machine **100** of the embodiment, the control system **500** of the working machine **100** operates the working machine **100** using an image from the working machine side. The working machine **100** includes an image processing unit **106** that converts a color image into a grayscale image, and a working machine communication unit as the communication unit **102** that transmits the grayscale image from the working machine side to the system side. The system **200** includes a system communication unit as a communication unit **202** that receives a grayscale image transmitted by the working machine **100**, and a processing unit **206** that restores a color image from the grayscale image, by the use of the learning model which is created, using an original image of the working area, and an image in which the tonal information is reduced from the original image.

(121) The system **200** can restore a color image from a grayscale image, by the use of a learning model which is created, using an original image of the work area, and an image in which the tonal information is reduced from the original image, by such a configuration. Therefore, the working machine **100** can report the situation to the operator of the system **200** with low delay, by converting the color image into a grayscale image and transmitting the grayscale image to the system **200**.

(122) When a remote control becomes necessary, the working machine **100** transmits the image information of a grayscale image, which is obtained by converting the image information of a color image, to the system **200**. Since the size of image information of a grayscale image is about one third of that of a color image, the delay is reduced, by transmitting the image information of a grayscale image, compared to a case of transmitting the image information of a color image. The system **200** inputs the image information of the grayscale image transmitted by the working machine **100** to the learning model and acquires the image information of the color image that is output by the learning model. As a result, it is possible to obtain a color image that clearly shows a sign or the like at a construction site, for example, while the delay is low.

(123) In the control system **500** of the working machine **100**, the image processing unit **106** creates an image obtained by lowering the resolution of the grayscale image, and the working machine communication unit transmits the image obtained by lowering the resolution of the grayscale image from the working machine side to the system side. The system communication unit receives an image obtained by lowering the resolution of the grayscale image, which is transmitted by the working machine **100**, and the processing unit **206** restores a color image from the image obtained by lowering the resolution of the grayscale image, by the use of a learning model that is created, using the original image of the working area, and the image obtained by lowering the resolution of the image in which the tonal information is reduced from the original image.

(124) With such a configuration, the system **200** can restore a color image from an image obtained by lowering the resolution of the grayscale image, by the use of a learning model that is created,

using the original image of the working area, and an image obtained by lowering the resolution of the image in which the tonal information is reduced from the original image. The capacity of the image information obtained by lowering the resolution of the grayscale image is further reduced than the capacity of the image information of the grayscale image. Therefore, the working machine **100** can report the situation to the operator of the system **200** with even less delay than in the case of transmitting the image information of a grayscale image.

Modified Example of Embodiment

(125) FIG. **1** can be applied to the modified example of the present embodiment. However, it differs in that a working machine **100***a* is provided instead of the working machine **100**. The working machine **100***a* differs in that it has a function of determining whether to learn the learning model again, in addition to the function of the working machine **100**.

(126) FIG. **5** is a diagram for explaining an example of the operation of the working machine according to the modified example of the present embodiment. For example, when operating the working machine **100***a* at a construction site, there is a case where new structures may appear as the progress of construction. The learning data used to create the learning model does not include image information of the structures. For this reason, there is a risk of a large difference between the color image obtained from the image information of the color image that is output when the image information of the grayscale image is input to the learning model, and the color image obtained from the image information of the color image before being converted into the image information of the grayscale image.

(127) The working machine **100***a* captures an image of the surroundings of the working machine **100***a* at an initial stage of construction. The working machine **100***a* stores one or a plurality of images IM**1** of the working area acquired by capturing the image of the surroundings of the working machine **100***a* in association with positional information at the time of image capturing and information indicating the attitude of the working machine **100***a* at the time of image capturing. An example of positional information is represented by a longitude and a latitude, and an example of information indicating the attitude is represented by a slope of the working machine **100***a* with respect to a predetermined direction such as north.

(128) The working machine **100***a* captures an image of the surroundings of the working machine **100***a* after the progress of construction. The working machine **100***a* stores one or a plurality of images IM**2** of the working area acquired by capturing the image of the surroundings of working machine **100***a*, in association with positional information at the time of image capturing and information indicating the attitude of working machine **100***a* at the time of image capturing. Here, the positional information when one or a plurality of images IM**2** are captured and the information indicating the attitude of working machine **100***a* at the time of image capturing may be the same as the positional information when one or a plurality of images IM**1** are captured and the information indicating the attitude of the working machine **100***a* at the time of image capturing, in the early stage of construction.

(129) The working machine **100***a* divides a plurality of object regions included in each of one or a plurality of images IM**1** of the working area acquired at the initial stage of construction and one or a plurality of images IM**2** of the working area acquired after the progress of construction. In FIG. **5**, as an example, a plurality of object regions are divided by different hatchings. The working machine **100***a* acquires one or a plurality of images SS**1** by dividing a plurality of object regions included in one or a plurality of images IM**1** of the working area and acquires one or a plurality of images SS**2** by dividing a plurality of object regions included in one or a plurality of images IM**2** of the working area.

(130) The working machine **100***a* determines whether to update the learning model on the basis of the acquired one or a plurality of images SS**1** and one or a plurality of images SS**2**. For example, the working machine **100***a* determines whether to relearn the learning model on the basis of a change in image SS**2** with respect to the image SS**1**. Specifically, the working machine **100***a*

creates a difference image DIM between the image SS**1** and the image SS**2**. Here, the image SS**1** and the image SS**2** are acquired from the image IM**1** and the image IM**2** captured at the same position and the same attitude. The working machine **100***a* determines whether the number of pixels in the difference portion is equal to or greater than a threshold value, on the basis of the created difference image DIM. The working machine **100***a* determines to relearn the learning model when the number of pixels in the difference portion is equal to or greater than the threshold value and determines not to relearn the learning model when the number of pixels in the difference portion is less than the threshold value.

(131) When the working machine **100***a* determines to relearn the learning model, the working machine **100***a* acquires image information in which the tonal information is reduced from each piece of the image information of one or a plurality of images IM**2**. For example, the working machine **100***a* converts the information into image information of a grayscale image in which tonal information is reduced from the image information of one or a plurality of images IM**2**.

(132) The working machine **100***a* transmits, to cloud server CS, one or plural pieces of learning data in which image information of one or a plurality of images IM**2** are associated with the image information of image obtained by reducing the tonal information from the one or a plurality of images IM**2**. The cloud server CS receives one or plural pieces of learning data transmitted by the working machine **100***a*. The cloud server CS stores one or plural pieces of learning data.

(133) The working machine **100***a*, the system **200**, the learning device **300**, and the cloud server CS of the modified example of the embodiment will be described below in detail with respect to the working machine **100***a* that is different from the embodiment. FIG. **6** is a diagram showing an example of a working machine according to a modified example of the embodiment. The working machine **100***a* is an autonomous traveling vehicle and travels along a route through navigation by the system **200**.

(134) The working machine **100***a* includes a communication unit **102**, a sensor **103**, a determination unit **104**, an image capturing unit **105**, an image processing unit **106**, a creation unit **108**, a control unit **110**, a position estimation unit **112**, a collection unit **114**, a relearning determination unit **116**, a drive device **140** and a storage unit **150**.

(135) The storage unit **150** stores a working area image information table. FIG. **7** is a diagram showing an example of the working area image information table. The working area image information table includes positional information of the working machine **100***a* when the image capturing unit **105** captures an image of the surroundings of the working machine **100***a*, and information indicating the attitude of the working machine **100***a* when the image capture unit **105** captures an image of the surroundings of the working machine **100***a*, and table type information obtained by associating one or more images of the working area acquired by capturing the image of the surroundings of the working machine **100***a*. Returning to FIG. **6**, the description is continued.

(136) The collection unit **114** causes the image capturing unit **105** to capture an image of the surroundings of the working machine **100***a* at the initial stage of construction. The collection unit **114** acquires the positional information of the working machine **100***a* from the position estimation unit **112**, when the image capturing unit **105** captures an image of the surroundings of the working machine **100***a*. The collection unit **114** acquires information indicating the attitude of the working machine **100***a*, when the image capturing unit **105** captures an image of the surroundings of the working machine **100***a*. For example, the collection unit **114** may include a 3-axis gyro sensor (not shown) and acquire information indicating the attitude from the 3-axis gyro sensor. The collection unit **114** stores the image information of one or a plurality of images IM**1** of the working area acquired by capturing the image of the surroundings of the working machine **100***a*, in the working area image information table of the storage unit **150**, in association with the positional information at the time of image capturing and the information indicating the attitude of the working machine **100***a* at the time of image capturing.

(137) The collection unit **114** causes the image capturing unit **105** to capture an image of the

surroundings of the working machine **100***a* after the progress of construction. The collection unit **114** acquires the positional information of the working machine **100***a* from the position estimation unit **112** when the image capturing unit **105** captures the image of the surroundings of the working machine **100***a*. The collection unit **114** acquires information indicating the attitude of the working machine **100***a* when the image capturing unit **105** captures the image of the surroundings of the working machine **100***a*. The collection unit **114** stores the image information of one or a plurality of images IM**2** of the working area acquired by capturing the image of the surroundings of working machine **100***a*, in the working area image information table of the storage unit **150**, in association with the positional information at the time of image capturing and the information indicating the attitude of the working machine **100***a* at the time of image capturing.

(138) The relearning determination unit **116** divides a plurality of object regions included in each of one or a plurality of images IM**1** of the working area acquired at the initial stage of construction and one or a plurality of images IM**2** of the working area acquired after the progress of construction. For example, the relearning determination unit **116** divides a sky region, a heavy machinery region, a structure region, a plant region, a ground region, and the like included in each of one or a plurality of images IM**1** and one or a plurality of images IM**2** of the working area. For example, the relearning determination unit **116** acquires one or a plurality of images SS**1** by dividing a plurality of object regions included in each of the one or a plurality of images IM**1** of the working area, and acquires one or a plurality of images SS**2** by dividing a plurality of object regions included in each of the one or a plurality of images IM**2** of the working area, by the use of an algorithm of deep learning in which labels and categories are associated with all pixels in the image, such as Semantic Segmentation.

(139) The relearning determination unit **116** determines whether to relearn the learning model on the basis of the acquired one or a plurality of images SS**1** and one or a plurality of images SS**2**. For example, the relearning determination unit **116** determines whether to relearn the learning model on the basis of a change in the image SS**2** with respect to the image SS**1**. Specifically, the relearning determination unit **116** creates a difference image DIM between the image SS**1** and the image SS**2**. The relearning determination unit **116** determines whether the number of pixels in the difference portion is equal to or greater than the threshold value, on the basis of the created difference image DIM. The relearning determination unit **116** determines that the learning model is relearned when updated if the number of pixels of the difference portion is equal to or greater than the threshold value, and that the learning model is not relearned if the number of pixels of the difference portion is less than the threshold value.

(140) When it is determined that the learning model is relearned by the relearning determination unit **116**, the image processing unit **106** acquires image information of one or a plurality of images IM**2**. The image processing unit **106** converts the acquired image information of one or a plurality of images IM**2** into image information of a grayscale image.

(141) The creation unit **108** creates a plurality of pieces of learning data in which the image information of the one or a plurality of images IM**2** is associated with the image information of the grayscale image obtained by converting the image information of the one or a plurality of images IM**2** from the image processing unit **106**. The creation unit **108** transmits one or a plurality of pieces of created learning data from the communication unit **102** to the learning device **300**.

(142) (Operations of Working Machine **100***a*, System **200**, Learning Device **300**, and Cloud Server CS)

(143) FIG. **8** is a flowchart showing an example of operations of the working machine, the system, the learning device, and the cloud server CS according to the modified example of the embodiment. Referring to FIG. **8**, an operation will be described in which after image information of one or a plurality of images IM**1** of the working area acquired at the initial stage of construction is associated with positional information at the time of image capturing and information indicating the attitude of the working machine **100***a* at the time of image capturing and is stored in the

working area image information table of the storage unit **150**, the working machine **100***a* determines whether to relearn the learning model, and when it is determined to update, the learning device **300** relearns the learning model and sets the learning model in the system **200**.

(144) (Step S**1**-**3**)

(145) The working machine **100***a* travels along the route of the working area.

(146) (Step S**2**-**3**)

(147) In the working machine **100***a*, the image capturing unit **105** acquires image information of one or a plurality of images IM**2** of the working area by capturing the image of the surroundings of the working machine **100***a*.

(148) (Step S**3**-**3**)

(149) In the working machine **100***a*, the collection unit **114** acquires the positional information of the working machine **100***a* from the position estimation unit **112** when the image capturing unit **105** captures the image of the surroundings of the working machine **100***a*. The collection unit **114** acquires information indicating the attitude of the working machine **100***a* when the image capturing unit **105** captures the image of the surroundings of the working machine **100***a*. The collection unit **114** stores image information of one or a plurality of images IM**2** of the working area acquired by capturing the image of the surroundings of working machine **100***a*, in the working area image information table of the storage unit **150**, in association with the positional information at the time of image capturing and the information indicating the attitude of the working machine **100***a* at the time of image capturing.

(150) (Step S**4**-**3**)

(151) In the working machine **100***a*, the relearning determination unit **116** divides the plurality of object regions included in each of one or a plurality of images IM**1** of the working area acquired at the initial stage of construction and one or a plurality of images IM**2** of the working area acquired after the progress of construction. The relearning determination unit **116** acquires one or a plurality of images SS**1** by dividing a plurality of object regions included in one or a plurality of images IM**1** of the working area and acquires one or a plurality of images SS**2** by dividing a plurality of object regions included in one or a plurality of images IM**2** of the working area. The relearning determination unit **116** determines whether to relearn the learning model on the basis of the acquired one or a plurality of images SS**1** and one or a plurality of images SS**2**. If it is determined not to relearn the learning model, the process returns to step S**1**-**3**.

(152) (Step S**5**-**3**)

(153) In the working machine **100***a*, the image processing unit **106** acquires image information of one or a plurality of images IM**2** when it is determined to relearn the learning model by the relearning determination unit **116**. The image processing unit **106** converts the acquired image information of one or a plurality of images IM**2** into image information of a grayscale image.

(154) (Step S**6**-**3**)

(155) In the working machine **100***a*, the creation unit **108** creates one or a plurality of pieces of learning data in which image information of one or a plurality of images IM**2** is associated with image information of a grayscale image obtained by converting the image information of one or a plurality of images IM**2** from the image processing unit **106**.

(156) (Step S**7**-**3**)

(157) In the working machine **100***a*, the creation unit **108** transmits one or more created learning data from the communication unit **102** to the cloud server CS.

(158) Since steps S**6**-**1** to S**11**-**1** of FIG. **3** can be applied to steps S**8**-**3** to S**13**-**3**, description thereof will not be provided.

(159) In the modified example of the above-described embodiment, as an example, although a case has been described in which it is determined whether to relearn the learning model on the basis of one or a plurality of images IM**1** of the working area acquired at the initial stage of construction and one or a plurality of images IM**2** of the working area acquired after the progress of

construction, the embodiment is not limited to this example. For example, whether to relearn the learning model may be determined on the basis of images acquired at each of a plurality of time points, without being limited to the initial stage of construction.

(160) According to a control system **500***a* according to the modified example of the embodiment, in a control system **500**, the working machine **100***a* includes a relearning determination unit **116** which determines whether to relearn the learning model on the basis of a plurality of object regions included in the color images acquired at a plurality of time points.

(161) With this configuration, the working machine **100***a* divides a plurality of object regions included in the color images acquired at each of a plurality of time points and can determine whether to relearn the learning model on the basis of the plurality of object regions. Therefore, by relearning the learning model, the accuracy of restoring the color image from the grayscale image can be improved.

(162) Further, in the control system **500***a*, the relearning determination unit **116** acquires a difference portion from a difference image between images obtained by dividing a plurality of objects included in the color images acquired at a plurality of time points for each object and determines whether to relearn the learning model on the basis of the acquired number of pixels in the difference portion.

(163) With this configuration, the working machine **100***a* can obtain a difference image between images obtained by dividing a plurality of objects included in the color images acquired at a plurality of time points for each object. Here, for example, the difference image is obtained on the basis of images captured at the same position and the same attitude. Since the working machine **100***a* can acquire the difference portion from the obtained difference image, it is possible to determine whether to relearn the learning model on the basis of the number of pixels of the acquired difference portion.

(164) In addition, in the control system **500***a*, the relearning determination unit **116** determines to relearn the learning model when the number of pixels in the difference portion is equal to or greater than the threshold value.

(165) With this configuration, since the working machine **100***a* can determine to relearn the learning model when the number of pixels in the difference portion is equal to or greater than the threshold value, it is possible to improve the accuracy of restoring the color image from the grayscale image by relearning the learning model.

(166) While preferred embodiments of the invention have been described and illustrated above, it should be understood that these are exemplary of the invention and are not to be considered as limiting. Additions, omissions, substitutions, and other modifications can be made without departing from the spirit or scope of the present invention. Accordingly, the invention is not to be considered as being limited by the foregoing description, and is only limited by the scope of the appended claims.

EXPLANATION OF REFERENCES

(167) **100**, **100***a* Working machine **102** Communication unit **103** Sensor **104** Determination unit **105** Image capturing unit **106** Image processing unit **108** Creation unit **110** Control unit **112** Position estimation unit **114** Collection unit **116** Relearning determination unit **140** Drive device **150** Storage unit **200** System **202** Communication unit **206** Processing unit **207** Operation unit **212** Display unit **250** Storage unit **300** Learning device **302** Communication unit **306** Processing unit **308** Creation unit **350** Storage unit **250** Storage unit **500** Control system

Claims

1. A control system of a working machine, which control system operates the working machine based on a working image from the working machine, wherein the working machine comprises: an image processing unit that converts a color image into a grayscale image; and a communication

unit that transmits the grayscale image from the working machine to the control system as the working image, wherein the working image comprises an image of surroundings of the working machine, and the control system comprising: a system communication unit that receives the working image transmitted by the working machine; and a processing unit that generates a restored color image from the working image, by use of a learning model that is based on an area image of a working area and a modified image in which tonal information is reduced from the area image, wherein the learning model employs data based on the area image of the working area and on the modified image to restore the working image to the restored color image.

2. The control system according to claim 1, wherein the image processing unit creates the working image by lowering a resolution of the grayscale image.

3. The control system according to claim 1, wherein the working machine further comprises: a relearning determination unit that determines whether to relearn the learning model on the basis of a plurality of object regions included in the color image acquired at a plurality of time points.

4. The control system according to claim 3, wherein the relearning determination unit acquires a difference portion from a difference image between images obtained by dividing the plurality of objects included in the color image acquired at a plurality of time points for each object and determines whether to relearn the learning model further on the basis of the number of pixels of the acquired difference portion.

5. The control system according to claim 4, wherein the relearning determination unit determines to relearn the learning model when the number of pixels of the difference portion is equal to or greater than a threshold value.

6. A control method of a working machine, which control method operates the working machine using a working image captured by the working machine, wherein the working machine converts a color image into a grayscale image, and wherein the working machine transmits the grayscale image from the working machine side to a control system side as the working image, wherein the working image comprises an image of surroundings of the working machine, and the control method comprising: receiving, by the control system, the working image transmitted by the working machine; and generating, by the control system, a restored color image from the working image, by use of a learning model that is based on an area image of a working area and a modified image in which tonal information is reduced from the area image, wherein the learning model employs data based on the area image of the working area and on the modified image to restore the working image to the restored color image.