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United States Patent	12385220
Kind Code	B2
Date of Patent	August 12, 2025
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Automated work system

Abstract

An automated operation controller **45** of an automated work system **10** includes: a work status management section **452** that selects a work content according to a work DB **456** that records a work plan for a hydraulic excavator **1** and a work order in the work plan, creates an operation plan based on the selected work content and information on the surrounding environment measured by laser scanners **34**, and outputs a control signal to a vehicle body controller **41** based on the operation plan; and an abnormal object detection section **454** that detects an abnormal object present on a work site based on the information on the surrounding environment measured by the laser scanners **34**. When the execution of the operation plan is determined to be hindered by the presence of the abnormal object, the work status management section **452** selects another work content from the work plan.

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Appl. No.:	**18/023454**
Filed (or PCT Filed):	**December 13, 2021**
PCT No.:	**PCT/JP2021/045900**
PCT Pub. No.:	**WO2022/168447**
PCT Pub. Date:	August 11, 2022

Prior Publication Data

Document Identifier	Publication Date
US 20230332377 A1	Oct. 19, 2023

Foreign Application Priority Data

JP	2021-014988	Feb. 02, 2021

Publication Classification

Int. Cl.: **E02F9/20** (20060101); **E02F9/26** (20060101)

U.S. Cl.:

CPC **E02F9/2054** (20130101); **E02F9/205** (20130101); **E02F9/262** (20130101);

Field of Classification Search

CPC: E02F (9/205); E02F (9/2054); E02F (9/26); E02F (9/261); E02F (9/262)

References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
2004/0158355	12/2003	Holmqvist et al.	N/A	N/A
2008/0208393	12/2007	Schricker	701/1	G08G 1/20
2020/0018045	12/2019	Sano et al.	N/A	N/A
2020/0159228	12/2019	Zhong	N/A	G05D 1/0088
2020/0299924	12/2019	Kurokawa et al.	N/A	N/A
2020/0356088	12/2019	Schlacks, IV et al.	N/A	N/A
2020/0362536	12/2019	Shimamura et al.	N/A	N/A
2021/0027634	12/2020	Li	N/A	G08G 5/32
2021/0034058	12/2020	Subramanian	N/A	G01S 17/86
2021/0168996	12/2020	Lee	N/A	G05D 1/0278
2021/0309352	12/2020	Elkins	N/A	E02F 9/261
2022/0074168	12/2021	Yamada et al.	N/A	N/A

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
5826130	12/1982	JP	N/A
S5826130	12/1982	JP	E02F 3/84
2016132912	12/2015	JP	N/A
2019159727	12/2018	JP	N/A
2020143481	12/2019	JP	N/A
2013-0087361	12/2012	KR	N/A
2018164172	12/2017	WO	N/A
2019167203	12/2018	WO	N/A

OTHER PUBLICATIONS

Kim et al., Intelligent navigation strategies for an automated earthwork system, 2011, Elsevier (Year: 2011). cited by examiner
Seo et al., Task planner design for an automated excavation system, 2011, Elsevier (Year: 2011). cited by examiner
International Search Report of PCT/JP2021/045900 dated Feb. 22, 2022. cited by applicant
Extended European Search Report received in corresponding European Application No. 21924832.5 dated Jul. 30, 2024. cited by applicant
Chinese Office Action received in corresponding Chinese Application No. 202180053538.7 dated May 24, 2025. cited by applicant

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Background/Summary

TECHNICAL FIELD
(1) The present invention relates to an automated work system, and especially relates to an automated work system that operates a work machine, such as a construction machine, by automated operation. The present application claims priority from Japanese patent application JP 2021-014988 filed on Feb. 2, 2021, the entire content of which is hereby incorporated by reference into this application.
BACKGROUND ART
(2) At a work site for civil engineering, construction, and the like, where a construction machine is used, in order to reduce a task burden of a worker and improve safeness, an automated work system in which the worker and the like outputs instructions and thereby causes the construction machine to operate by automated operation is developed. For example, in Patent Literature 1, a technique that enables an automated operation of a plurality of construction machines by a small number of workers is described.
(3) More specifically, in the technique described in Patent Literature 1, construction position information is output from a construction management section to the respective plurality of construction machines, and thereby the respective plurality of construction machines are caused to operate by automated operation using the construction position information. Thus, by causing the plurality of construction machines to operate by automated operation under the management of the construction management section, a highly efficient construction is made possible even by a small number of workers.
CITATION LIST
Patent Literature
(4) Patent Literature 1: JP 2016-4329U A
SUMMARY OF INVENTION
Technical Problem
(5) However, on a work site, there is a case where an abnormal object, such as a buried object, for example, is excavated and hinders the automated operation of a construction machine. Patent Literature 1 includes a description that, when a situation different from normal occurs while an operator of the construction machine is visually observing the construction range, an operation of stopping the operation of the construction machine or the like is performed according to the

situation. That is, both a recognition of the occurrence of the situation different from normal and its handling need to be performed by the operator. Therefore, productivity of the entire operation decreases and becomes a problem.
(6) The present invention has an object to provide an automated work system in which, even when an abnormal object that hinders continuation of work appears, an automated operation of a work machine on a work site can be continued without needing a handling by an operator, and a decrease in productivity can be avoided.
Solution to Problem
(7) An automated work system according to the present invention is an automated work system comprising a surrounding environment measuring device that measures a surrounding environment of a work machine and an automated operation controlling device that controls an automated operation of the work machine. The automated operation controlling device includes a work status management section that selects a work content according to a work order in an obtained work plan, creates an operation plan for the work machine based on the selected work content and information on the surrounding environment measured by the surrounding environment measuring device, and outputs a control signal to a vehicle body controller disposed in the work machine based on the created operation plan, so as to manage a work status of the work machine, and an abnormal object detection section that detects an abnormal object present on a work site where the work plan is executed based on the information on the surrounding environment measured by the surrounding environment measuring device. When an abnormal object is detected by the abnormal object detection section, the work status management section determines whether or not an execution of the operation plan is to be hindered by the presence of the abnormal object, and when the execution of the operation plan is determined to be hindered by the presence of the abnormal object, the work status management section selects another work content from the work plan.
(8) In the automated work system according to the present invention, when an abnormal object is detected, the work status management section of the automated operation controlling device determines whether or not the execution of the operation plan is to be hindered by the presence of the abnormal object, and when the execution of the operation plan is determined to be hindered by the presence of the abnormal object, selects another work content from the work plan. Therefore, even when an abnormal object that hinders continuation of work appears, the work status management section selects another work that is executable, thereby allowing continuation of work by automated operation, and a decrease in productivity can be avoided.
Advantageous Effects of Invention
(9) According to the present invention, even when an abnormal object that hinders continuation of work appears, an automated operation of a work machine on a work site can be continued without needing a handling by an operator, and a decrease in productivity can be avoided.

Description

BRIEF DESCRIPTION OF DRAWINGS
(1) FIG. **1** is a perspective view illustrating a hydraulic excavator.
(2) FIG. **2** is a block diagram illustrating a configuration of the hydraulic excavator,
(3) FIG. **3** is a drawing illustrating an exemplary work site of civil engineering.
(4) FIG. **4** is a block diagram illustrating a configuration of an automated work system in a first embodiment.
(5) FIG. **5** is a plan view illustrating an exemplary excavation area where an abnormal object has been detected on a work site.
(6) FIG. **6** is a side view illustrating an exemplary excavation area where an abnormal object is detected on a work site.

(7) FIG. **7** is a side view illustrating an exemplary excavation area where an abnormal object is detected on a work site.
(8) FIG. **8** is a flowchart indicating a control process of an automated operation controller.
(9) FIG. **9** is a flowchart indicating a control process of the automated operation controller.
(10) FIG. **10** is a flowchart indicating a control process of an automated operation controller in an automated work system according to a second embodiment.
(11) FIG. **11** is an example illustrating a content displayed on a monitor.
(12) FIG. **12** is a block diagram illustrating a configuration of an automated work system according to a third embodiment.

DESCRIPTION OF EMBODIMENTS

(13) The following describes embodiments of an automated work system according to the present invention with reference to the drawings. In the descriptions of the drawings, same reference numerals are given to the same elements, and overlapping descriptions will be omitted. The present invention is not limited to these drawings and includes cases where a part of the configuration elements are not used, and the configuration elements of the respective embodiments described in the following can be appropriately combined.

First Embodiment

(14) An automated work system **10** according to the present embodiment is a system mounted on a work machine, for example, to cause the work machine to operate by automated operation. Here, since a description is given using a hydraulic excavator **1** as the work machine, the automated work system **10** of the present embodiment is mounted on the hydraulic excavator **1**. Note that, the work machine is not limited to the hydraulic excavator **1**, and may be, for example, a wheel loader, a bulldozer, or the like.
(15) [Hydraulic Excavator]
(16) FIG. **1** is a perspective view illustrating a hydraulic excavator, and FIG. **2** is a block diagram illustrating a configuration of the hydraulic excavator. The hydraulic excavator **1** includes a lower traveling body **4** that travels by a power system, an upper swing body **3** installed to be swingable in a right-left direction with respect to the lower traveling body **4**, and a working assembly **2** that is installed to the upper swing body **3** and performs work such as excavation. The lower traveling body **4** includes a right-left pair of crawlers **44**, and the respective crawlers **44** are driven by hydraulic travel motors **26***b*, **26***c*. The upper swing body **3** is swung driven by a hydraulic swing motor **26***a*. Note that, in the following description, the hydraulic swing motor **26***a* and the hydraulic travel motors **26***b*, **26***c* are collectively referred to as “hydraulic motors **26**” in some cases.
(17) The working assembly **2** is configured turnably in a vertical direction with respect to the upper swing body **3**. This working assembly **2** includes a boom **20** coupled to the upper swing body **3**, an arm **21** coupled to the boom **20**, a bucket **22** coupled to the arm **21**, boom cylinders **23***a* that drive the boom **20**, an arm cylinder **23***b* that drives the arm **21**, and a bucket cylinder **23***c* that drives the bucket **22** via first bucket links **24** and a second bucket link **25**.
(18) Both ends of the boom cylinders **23***a* are respectively coupled to the upper swing body **3** and the boom **20**. The boom **20** turns in the vertical direction with respect to the upper swing body **3** according to an expansion and contraction of the boom cylinders **23***a*. Both ends of the arm cylinder **23***b* are respectively coupled to the boom **20** and the arm **21**. The arm **21** turns in a vertical direction with respect to the boom **20** according to the expansion and contraction of the arm cylinder **23***b*.
(19) Both ends of the bucket cylinder **23***c* are respectively coupled to the arm **21** and the first bucket links **24**. The first bucket link **24** has one end turnably coupled to the bucket cylinder **23***c*, and the other end turnably coupled to the second bucket link **25**. The second bucket link **25** has one end coupled to the first bucket links **24**, and the other end turnably coupled to the bucket **22**. The arm **21**, the first bucket links **24**, the second bucket link **25** and the bucket **22** constitute a four-joint link mechanism. When the bucket cylinder **23***c* expands or contracts, the first bucket links **24**

relatively turn with respect to the arm **21**, and in conjunction with that, the bucket **22** constituting the four-joint link mechanism also turns in the vertical direction with respect to the arm **21**.
(20) The hydraulic excavator **1** thus configured drives the boom cylinders **23***a*, the arm cylinder **23***b*, and the bucket cylinder **23***c* to appropriate positions, and thereby can drive the bucket **22** to any position and any posture to perform work such as excavation. The boom cylinders **23***a*, the arm cylinder **23***b*, and the bucket cylinder **23***c* are each configured of a hydraulic cylinder, for example. Note that, in the following description, these cylinders are collectively referred to as "hydraulic cylinders **23**" in some cases.
(21) On the upper swing body **3**, two Global Navigation Satellite System (GNSS) antennas **31***a*, **31***b* are arranged. GNSS refers to a satellite positioning system that is a global navigation satellite system, which receives signals from a plurality of positioning satellites and obtains its own position on earth. The GNSS antennas **31***a*, **31***b* receive signals (in other words, radio waves) from a plurality of GNSS satellites (not illustrated) positioned in the sky above the earth, and output the received signals to a GNSS controller **32**. The GNSS controller **32** computes the positions (such as latitudes, longitudes, and elevations) of the respective GNSS antennas **31***a*, **31***b* on earth based on the signals from the GNSS antennas **31***a*, **31***b*.
(22) Note that, various types of this satellite positioning method exist, and the present invention is not limited to any of these. For example, a method called Real Time Kinematic-GNSS (RTK-GNSS) of receiving correction information from a base station that includes a GNSS antenna located at a site and obtaining its own position with even higher accuracy may be used. In this case, the hydraulic excavator **1** needs a receiver for receiving the correction information from the base station but the own positions of the GNSS antennas **31***a*, **31***b* can be measured with even better accuracy.
(23) By preliminarily locating the arranged positions of the GNSS antennas **31***a*, **31***b* on the upper swing body **3**, the position of the upper swing body **3** on earth can be obtained by inversely calculating from arranged positions of the GNSS antennas **31***a*, **31***b*. Further, since the two GNSS antennas **31***a*, **31***b* are both mounted on the upper swing body **3**, an orientation (for example, which directions the boom **20**, the arm **21**, and the bucket **22** are facing) of the upper swing body **3** can also be obtained. Note that, in the following description, the GNSS antennas **31***a*, **31***b* are collectively referred to as "GNSS antennas **31**" in some cases.
(24) In addition, a vehicle body Inertial Measurement Unit (IMU) **28***a* for measuring an inclination of the upper swing body **3** is installed to the upper swing body **3**. Similarly, a boom IMU **28***b* for measuring an inclination of the boom **20** is installed to the boom **20**, an arm IMU **28***c* for measuring an inclination of the arm **21** is installed to the arm **21**, and a bucket IMU **28***d* for measuring an inclination of the first bucket link **24** is installed to the first bucket links **24**, respectively. Note that, in the following description, these IMUs are collectively referred to as "IMUs **28**" in some cases.
(25) The IMUs **28** are sensor units that can measure acceleration rates and angular velocities, and output the results of the measured acceleration rates and angular velocities to an automated operation controller **45** described below. The automated operation controller **45** can obtain postures of the IMUs **28** based on the measured values of the acceleration rates and the angular velocities output from the IMUs **28**. That is, the automated operation controller **45** can obtain a forward-backward inclination and a right-left inclination of the upper swing body **3** based on the measurement result of the vehicle body IMU **28***a*, a turning posture of the boom **20** based on the measurement result of the boom IMU **28***b*, and a turning posture of the arm **21** based on the measurement result of the arm IMU **28***c*, respectively.
(26) On the other hand, regarding a tanning posture of the bucket **22**, the automated operation controller **45** first obtains turning postures of the first bucket links **24** based on the measurement result of the bucket IMU **28***d*, next computes based on the turning posture of the arm **21** and dimension information on the four-joint link mechanism constituted of the arm **21**, the first bucket

links **24**, the second bucket link **25** and the bucket **22**, and thereby can obtain the turning posture of the bucket **22**.

(27) Thus, since the position, orientation, forward-backward inclination, and right-left inclination of the upper swing body **3** can be obtained based on the GNSS antenna **31** and the vehicle body IMU **28***a*, it is possible to obtain at which position on earth and in what sort of posture the upper swing body **3** is present. In addition, by having the respective dimension information on the boom **20**, the arm **21**, the bucket **22**, a position of a distal end **27** of the bucket **22** with respect to the upper swing body **3** can be obtained based on these dimension information, and the respective turning postures of the boom **20**, the arm **21**, and the bucket **22** obtained from the boom IMU **28***b*, the arm IMU **28***c*, and the bucket IMU **28***d*. That is, it is possible to obtain at which position on earth and in what sort of posture the working assembly **2** including the bucket **22** is present. The distal end **27** of the bucket **22** is namely a distal end of the working assembly **2**, and will be simply referred to as a "bucket distal end **27**" in the following.

(28) The hydraulic excavator **1** further includes a swing angle sensor **33** and laser scanners **34**. The swing angle sensor **33** is a sensor that measures a swing angle between the upper swing body **3** and the lower traveling body **4**, and is configured of, for example, a rotary encoder and the like. The swing angle sensor **33** outputs its measurement result to the automated operation controller **45**.

(29) The laser scanners **34** correspond to the "surrounding environment measuring device" described in the appended claims, and are respectively arranged in the front, back, right, and left directions of the upper swing body **3** to measure the surrounding environment (such as the surrounding terrain and objects) of the hydraulic excavator **1**. More specifically, the laser scanners **34** irradiate a constant range in a horizontal direction and a perpendicular direction with a laser light to measure a three-dimensional point cloud data of the terrain and objects around the vehicle body of the hydraulic excavator **1**. Then, the laser scanners **34** output the measured information on the surrounding environment to the automated operation controller **45**, For example, the laser scanners **34** output the measured three-dimensional point cloud data of around the vehicle body as position information based on the vehicle body to the automated operation controller **45**. Thus, by providing the laser scanners **34**, the shapes of the terrain and objects around the hydraulic excavator **1** become measurable.

(30) While the IMUS **28** are used to measure the postures of the respective parts of the working assembly **2** in the present embodiment, the present invention is not limited to the BTUs **28**, and as long as similar information can be obtained, a potentiometer, a cylinder stroke sensor, and the like may be used. Further, while the laser scanners **34** are used to measure the shapes of the terrain and objects around the vehicle body in the present embodiment, the present invention is not limited to the laser scanners **34**, and as long as similar information can be obtained, a stereo camera and the like may be used. When using a stereo camera, three-dimensional orthogonal coordinates are obtained by a triangulation method. Accordingly, calculating three-dimensional polar coordinate systems with measurement centers of the sensors on the respective points as the origins from the arranged positions of the sensors and the obtained orthogonal coordinates can obtain a distance to an object and information on the measured distance.

(31) As illustrated in FIG. **2**, the hydraulic excavator **1** further includes an engine **35**, a pilot hydraulic pump **36**, a main hydraulic pump **37**, a directional control valve **38**, a shut-off valve **39**, control valves **40***a* to **401**, and a control lever **30** constituted of an arm control lever **30***a*, a boom control lever **30***b*, a bucket control lever **30***c*, a swing control lever **30***d*, and travel control levers **30***e*, **30***f*, the GNSS controller **32**, a vehicle body controller **41**, a monitor **42**, a changeover switch **43**, and the automated operation controller **45**. Note that, in the following description, the control valves **40***a* to **401** are collectively referred to as "control valves **40**" in some cases.

(32) The pilot hydraulic pump **36** and the main hydraulic pump **37** are each driven by the engine **35** to supply pressure oil into the hydraulic circuit. Here, oil supplied by the pilot hydraulic pump **36** is referred to as pilot oil, and oil supplied by the main hydraulic pump **37** is referred to as hydraulic

oil for distinction. The pilot oil supplied from the pilot hydraulic pump **36** passes through the shut-off valve **39** and the control valves **40** to be transmitted to the directional control valve **38**. The shut-off valve **39** and the control valves **40** are each electrically connected to the vehicle body controller **41**, and the opening and closing of the shut-off valve **39** and the valve opening degree of the control valve **40** can be controlled by the vehicle body controller **41**.

(33) The directional control valve **38** controls flow rates and directions of the hydraulic oil supplied from the main hydraulic pump **37** to the respective hydraulic cylinders **23** and the respective hydraulic motors **26**, and how much hydraulic oil in which direction is to be flowed to which of the hydraulic cylinders **23** or the hydraulic motors **26** is determined according to the pilot oil having passed through the control valve **40**. Specifically, a flow rate of a hydraulic oil that drives the arm cylinder **23***b* in one direction is determined inside the directional control valve **38** according to a pilot oil transmitted to the directional control valve **38** having passed through the control valve **40***a*, and a flow rate of a hydraulic oil that drives the arm cylinder **23***b* in another direction is determined inside the directional control valve **38** according to a pilot oil transmitted to the directional control valve **38** having passed through the control valve **40***b*.

(34) Similarly, a flow rate of a hydraulic oil that drives the boom cylinders **23***a* by a pilot oil having passed through the control valves **40***c*, **40***d*, a flow rate of a hydraulic oil that drives the bucket cylinder **23***c* by a pilot oil having passed through the control valves **40***e*, **40***f*, a flow rate of a hydraulic oil that drives the hydraulic swing motor **26***a* by a pilot oil having passed through the control valves **40***g*, **40***h*, a flow rate of a hydraulic oil that drives the hydraulic travel motor **26***b* by a pilot oil having passed through the control valves **40***i*, **40***j*, and a flow rate of a hydraulic oil that drives the hydraulic travel motor **26***c* by a pilot oil having passed through the control valves **40***k*, **401** are each determined inside the directional control valve **38**.

(35) The control lever **30** outputs a voltage or a current according to an operation amount of the respective levers, and is electrically connected to the vehicle body controller **41**. The respective operation amounts of the control levers **30** are readable by the vehicle body controller **41**.

(36) Here, a basic process for the vehicle body controller **41** to perform a vehicle body operation in a manned operation state will be described. That is, the vehicle body controller **41** receives an operation input from the control lever **30** and first determines in which direction and at how much speeds (in other words, target speeds) the respective actuators (namely, the respective hydraulic cylinders and the respective hydraulic motors) are to be operated.

(37) Next, the vehicle body controller **41** determines the pressure of pilot oil (in other words, a target pilot pressure) supplied to the respective parts of the directional control valve **38** based on the determined direction and target speed. At this time, the vehicle body controller **41** has a conversion map between a pilot pressure and an actuator speed that indicates in which direction and at how much speed the respective actuators operate by how much pilot pressure being supplied to the respective parts of the directional control valve **38**, and by applying this, the target speed can be converted into the target pilot pressure.

(38) Once the target pilot pressure is obtained, the vehicle body controller **41** adjusts the valve opening degree of any of the control valves **40** corresponding to an actuator that is desired to be operated and its direction, and controls such that a pilot pressure for the target flow rate is supplied to the directional control valve **38**. At this time, in a case where the valve opening degrees of the control valves **40** are controlled by a current output from the vehicle body controller **41**, the vehicle body controller **41** has a conversion map between the current and the pilot pressure that indicates, for example, how much pilot pressure is supplied by flowing how much current to each of the control valves **40**, and by applying this, an output current to the control valves **40** can be obtained by the target pilot pressure, and the valve opening degrees of the control valves **40** can be controlled such that the pilot pressure that passes through the control valves **40** becomes a pressure according to the target.

(39) Thus, in the manned operation state, the vehicle body controller **41** controls the valve opening

degrees of the control valves **40***a*, **40***b* according to the operation amount of the arm control lever **30***a*, controls the valve opening degrees of the control valves **40***c*, **40***d* according to the operation amount of the boom control lever **30***b*, controls the valve opening degrees of the control valves **40***e*, **40***f* according to the operation amount of the bucket control lever **30***c*, controls the valve opening degrees of the control valves **40***g*, **40***h* according to the operation amount of the swing control lever **30***d*, controls the valve opening degrees of the control valves **40***i*, **40***j* according to the operation amount of the travel control lever **30***e*, and controls the valve opening degrees of the control valves **40***k*, **401** according to the operation amount of the travel control lever **30***f*. Accordingly, by the operator operating each of the respective control levers **30**, the arm **21**, the boom **20**, the bucket **22**, the upper swing body **3**, the left crawler, and the right crawler can be driven, and by operating the control levers **30**, any work such as moving the hydraulic excavator **1** can be executed.

(40) As described above, the vehicle body controller **41** can also control the opening and closing of the valve of the shut-off valve **39**, When the shut-off valve **39** closes, supply of the pilot oil to the control valves **40** and the directional control valve **38** is cut off. Accordingly, the respective actuators become unable to operate, and therefore the vehicle body controller **41** can stop the operations of all the actuators with more certainty.

(41) As described above, the GNSS controller **32** computes the position (for example, latitude, longitude, and elevation) of the GNSS antenna **31** on earth based on the signal of the GNSS satellite output from the GNSS antenna **31**, and outputs the computed result to the automated operation controller **45**.

(42) The changeover switch **43** is a switch for switching the manned operation state (in other words, manual control) and an unmanned automated operation state (in other words, automated control) of the hydraulic excavator **1**, and is arranged in at least one of the inside or the outside of a cab in the upper swing body **3**, The changeover switch **43** is connected to each of the automated operation controller **45** and the vehicle body controller **41**, and the automated operation controller **45** and the vehicle body controller **41** are switched between the manned operation state and the unmanned automated operation state based on a signal obtained from the changeover switch **43**.

(43) The monitor **42** corresponds to an "information input device" described in the appended claims, and accepts input from a work administrator, the operator, and the like. Specifically, the monitor **42** is, for example, a touch-panel type input/output device and is arranged in at least one of the inside or the outside of a cab in the upper swing body **3**. This monitor **42** is used for inputting a work content of the unmanned automated operation. For example, the work administrator can input the work content (such as excavation and loading, slope shaping, and slope tamping), a working range, a target shape, and the like to the automated operation controller **45** via the monitor **42**. In addition, by operating the touch panel of the monitor **42**, the work administrator, the operator, and the like can edit a work plan recorded in a work DB **456** (described later).

(44) In addition, the monitor **42** also functions as an "information display device" described in the appended claims, and displays the work content selected by a work status management section **452** and an executing range of the work, information on an abnormal object by which the execution of the operation plan is to be hindered, and the like. For example, the monitor **42** is electrically connected to the work DB **456**, obtains the work plan recorded in the work DB **456**, and displays a work content currently being executed by the hydraulic excavator **1**, its progress status, and the like. In addition, the monitor **42** may display the work plan recorded in the work DB **456** in the form of Table 1 or Table 2 described below. Further, when the work plan recorded in the work DB **456** has terminated, the monitor **42** may display the fact that the work plan has terminated. In addition, the monitor **42** is electrically connected to the work status management section **452** (described later), and obtains and displays information on whether the hydraulic excavator **1** is in the manned operation state or the unmanned automated operation state from the work status management section **452**.

(45) Thus, by one monitor **42** functioning as both the "information input device" and the "information display device," the component parts of the automated work system **10** can be reduced, and compactification of the automated work system **10** can be achieved.
(46) The vehicle body IMU **28***a*, the boom IMU **28***b*, the arm IMU **28***c*, the bucket IMU **28***d*, the GLASS controller **32**, the swing angle sensor **33**, the laser scanners **34**, the monitor **42**, and the changeover switch **43** are each connected to the automated operation controller **45**.
(47) The automated operation controller **45** corresponds to an "automated operation controlling device" described in the appended claims, and controls the automated operation of the hydraulic excavator **1**. The automated operation controller **45** is constituted of, for example, a microcomputer made by combining a Central Processing Unit (CPU) that executes a computation, a Read Only Memory (ROM) as a secondary storage device that records a program for the computation, and a Random Access Memory (RANI) as a temporary storage device that saves a computing process and temporal control variables, and performs control regarding the automated operation of the hydraulic excavator **1** by the execution of the stored program. Note that, while, in the present embodiment, the automated operation controller **45** is assumed to be mounted on the hydraulic excavator **1**, the automated operation controller **45** may be configured to be arranged outside the hydraulic excavator **1**, and be able to communicate with the hydraulic excavator **1** via wireless communication or the like.
(48) In the present embodiment, on a work site **5** on which the hydraulic excavator **1** performs work in the unmanned automated operation state (see FIG. **3**), the automated operation controller **45** gives an operation instruction for completing the work plan (described later) to the vehicle body controller **41** and thereby causes the hydraulic excavator **1** to operate by automated operation.
(49) FIG. **3** illustrates an exemplary work site of civil engineering. As illustrated in FIG. **3**, a plurality of excavation areas **51** to **54** exist on the work site **5**. The excavation areas **51** to **54** are regions in which the hydraulic excavator **1** digs dirt by performing excavation. In the excavation areas **51** to **54**, a three-dimensional terrain shape desired to be created after the excavation by the hydraulic excavator **1** is defined in the work plan as a designed terrain **6** (see FIG. **6**). The work plan describes an excavation order such as in what order the hydraulic excavator **1** excavates the plurality of excavation areas **51** to **54**.
(50) On the work site **5**, the hydraulic excavator **1** first drives the boom cylinders **23***a*, the arm cylinder **23***b*, and the bucket cylinder **23***c*, and thereby performs excavation to store the dirt into the bucket **22**. Next, the hydraulic excavator **1** drives the hydraulic swing motor **26***a* and the hydraulic travel motors **261**), **26***c* to move up to a dumping site **50** provided on the work site **5**, and further drives the boom cylinders **23***a*, the arm cylinder **23***b* and the bucket cylinder **23***c* to dump the dirt inside the bucket **22** to the dumping site **50**.
(51) FIG. **4** is a Hock diagram illustrating a configuration of the automated work system in the first embodiment. The automated work system **10** in the present embodiment is constituted of the laser scanners **34**, the vehicle body controller **41**, the monitor **42**, the changeover switch **43**, and the automated operation controller **45**, described above. The automated operation controller **45** includes a measured data processing section **451**, the work status management section **452**, a computation section **453**, an abnormal object detection section **454**, an object Data Base (DB) **455**, and the work Data. Base (DB) **456**. Meanwhile, the vehicle body controller **41** is configured including a vehicle body control section **411**.
(52) [Measured Data Processing Section]
(53) The measured data processing section **451** is electrically connected to each the IMUs **28**, the GNSS controller **32**, the swing angle sensor **33**, and the laser scanners **34**, and the measured data processing section **451**, based on information from the IMUs **28**, the GNSS controller **32**, the swing angle sensor **33**, and the laser scanners **34**, computes the tilting angle, position, orientation, and swing angle of the upper swing body **3**; the turning postures of the respective parts of the working assembly **2**, and the current terrain of around the vehicle body.

(54) Specifically, the automated operation controller **45**, based on the measurement results of the acceleration rate and angular velocity from the respective IMUs **28**, computes each the forward-backward inclination and right-left inclination of the upper swing body **3**, the turning posture of the boom **20**, the turning posture of the arm **21**, and the turning posture of the bucket **22**. For example, regarding the measurement results from the IMUs **28**, the automated operation controller **45** uses, for example, a complementary filter or a Kalman filter, which uses information such as an angle according to an integral process of an angular velocity or an angle formed with the gravity direction according to an obtained gravitational acceleration rate to obtain three-dimensional angles with respect to the gravity direction of the IMUs **28** themselves, and by preliminarily calibrating installation postures of the respective IMUs **28** with respect to respective installation parts of the hydraulic excavator **1**, obtains the turning postures of the upper swing body **3**, the boom **20**, the arm **21**, and the first bucket links **24** from the tilting angles of the respective BTUs **28** themselves, and further, as described above, obtains the turning posture of the bucket **22** from the turning postures of the arm **21** and the first bucket links **24**.
(55) In addition, the automated operation controller **45** obtains the positions (for example, latitudes, longitudes, and elevations) of the GNSS antennas **31***a*, **31***b* on earth computed by the GNSS controller **32**.
(56) In addition, the automated operation controller **45**, based on the measurement result of the swing angle sensor **33**, obtains a swing angle between the upper swing body **3** and the lower traveling body **4**.
(57) Further, the automated operation controller **45**, based on the three-dimensional point cloud data around the vehicle body measured by the laser scanners **34**, and information on the arranged positions and the arranged postures of the laser scanners **34** with respect to the upper swing body **3**, aggregates the information obtained from the plurality of laser scanners **34** into one three-dimensional point cloud data with the vehicle body as the base. In the present embodiment, four laser scanners **34** are disposed to the upper swing body **3**, and by aggregating the information obtained from these laser scanners **34**, a three-dimensional point cloud data of the entire surrounding of the vehicle body is measured. Note that, when using a sensor having a sufficient measurement range, it is possible to reduce the number of the laser scanners **34**, and the number may be increased for reasons such as to include redundancy.
(58) The measured data processing section **451** uses the arranged positions of the laser scanners **34** on the vehicle body to compute the arranged positions of the laser scanners **34** on the vehicle body in a vehicle body coordinate system. In addition, the measured data processing section **451** uses the arranged positions of the GNSS antenna **31***a*, **31***b* on the vehicle body and their positions on earth, and the arranged positions of the laser scanners **34** on the vehicle body in the vehicle body coordinate system to convert the position information of the three-dimensional point cloud data around the vehicle body obtained from the laser scanners **34** into a global coordinate system as the position information on earth. Further, based on the three-dimensional point cloud data around the vehicle body obtained from the laser scanners **34**, the measured data processing section **451** computes the current terrain as the terrain shape data around the hydraulic excavator **1**.
(59) Then, the measured data processing section **451** outputs the tilting angle, position, orientation, and swing angle of the upper swing body **3**, turning postures of the respective parts of the working assembly, and the computation result of the current terrain around the vehicle body to the computation section **453**, In addition, the measured data processing section **451** outputs the computation result of the current terrain around the vehicle body to the work status management section **452**.
(60) [Work DB]
(61) The work DB **456** corresponds to a “work recording section” described in the appended claims. A work plan and its progress status are recorded in the work DB **456**, The work plan includes a work content, a work order, and the like executed by at least one hydraulic excavator **1**.

The work content is, for example, excavation and loading, slope shaping, or the like, and regarding the work order, for example, ID numbers are assigned to a plurality of excavation areas, and the work order is determined in the order of the assigned ID numbers. The above-described excavation order is the work order of the excavation work (that is, the work content).
(62) Table 1 is an exemplary work plan recorded in the work DB **456**. As indicated in table 1, the work plan includes at least elements such as a “work ID,” an “excavation area ID,” a “work status,” a “remaining work amount” and a “work amount,” and elements other than these may also be included.
(63) TABLE-US-00001 TABLE 1 Remaining Excavation Area Work Work Work ID ID Work Status Amount Amount Work 51 Excavation Area 51 Completed 0% 1000 Work 52 Excavation Area 52 Halted 55% 2000 Work 53 Excavation Area 53 Not Yet Started 100% 3000 Work 54 Excavation Area 54 Not Yet Started 100% 1500 . . . .
(64) The “work ID” is an ID for identifying the respective works, and it is assumed in the present embodiment that the works are executed in the ascending order of the number of the “work ID.” The “excavation area ID” is an ID for identifying the respective excavation areas **51** to **54**, and the designed terrain **6** having a three-dimensional terrain shape desired to be created by the excavation operation of the hydraulic excavator **1** is associated with the “excavation area ID.” In the “work status,” four states “completed,” “halted,” “in progress,” and “not yet started” exist. The “remaining work amount” is a percentage indicating remaining amounts of the respective works. The “work amount” is an “amount of dirt that needs to be excavated before starting the work until creating the designed terrain.”
(65) The “remaining work amount” is a value obtained by dividing the “amount of dirt that needs to be excavated from the current terrain until creating the designed terrain” by the “work amount,” and converting the amount into percentage. The “amount of dirt that needs to be excavated from the current terrain until creating the designed terrain” and the “amount of dirt that needs to be excavated before starting the work until creating the designed terrain” are calculated as a volume by the work status management section **452** based on the current terrain. The “work status” of a work whose “remaining work amount” has reached 0% is “completed.” The “work status” of a work whose “remaining work amount” is 100% is “not yet started.” The “work status” of a work that has been halted without the “remaining work amount” reaching 0% is “halted.” The “work status” of a work whose work instruction is being given to the hydraulic excavator **1** is “in progress.” These “remaining work amount” and “work status” are also parameters indicating the progress status of the work. Note that, the designed terrain **6** as a three-dimensional terrain shape associated with the “excavation area ID” in the work plan recorded in the work DB **456** is editable via an input to the monitor **42**.
(66) [Object DB]
(67) The object DB **455** corresponds to an “object recording section” described in the appended claims, and records at least one of information on a predicted present object that is predicted to be present on the work site **5** or information on an unpredicted present object other than the predicted present object. In the present embodiment, the object DB **455** records information on an abnormal object **7** (namely, the predicted present object) that could become a hinderance element of work when the hydraulic excavator **1** performs the work on the work site **5**. Specifically, a things such as a large stone, a water pipe, or a wide range of mud caused by rainfall is considered as the abnormal object **7** that could become a work hinderance element. In addition, the object DB **455** records a three-dimensional point cloud data as a feature value required for detecting the abnormal object **7** by an object detection technique. Note that, the object DB **455** may record information on an abnormal object (namely, the unpredicted present object) that would not become a hinderance element of work when performing the work. Accordingly, it is possible to widely deal with the detection of various abnormal objects.
(68) [Abnormal Object Detection Section]

(69) Based on the measurement results of the laser scanners **34**, the abnormal object detection section **454** detects an abnormal object that is present on the work site where the above-described work plan is executed. Specifically, the abnormal object detection section **454** first obtains the three-dimensional point cloud data from the laser scanners **34**, and uses point cloud three-dimensional coordinate information to obtain information on the position and shape of the object around the hydraulic excavator **1**, Here, the position of the object is a point cloud barycentric coordinate calculated using the three-dimensional coordinates of each point where the detected object was measured. The shape of the object is a rectangular parallelepiped calculated with its depth, width, and height being the distances between a maximum value and a minimum value of the respective X, Y, and Z coordinates from the three-dimensional coordinate of each point. A detection method of the position and shape of the object may be any method that allows obtaining object information from the three-dimensional point cloud, such as, for example, the known Occupancy Grid Map (OGM) method.
(70) Next, the abnormal object detection section **454** acquires object information as the three-dimensional point cloud data recorded in the object DB **455**, and performs a detection of an abnormal object by determining whether or not the abnormal object **7** recorded as object information is present in the objects obtained by the laser scanners **34**. Specifically, the abnormal object detection section **454** uses, for example, SSD as an object detection technique utilizing Deep Learning and the like, and based on a concordance rate between the three-dimensional point cloud data of the object obtained from the laser scanners **34** and the three-dimensional point cloud data of the acquired object information, detects an abnormal object that is present on the work site **5**. For example, when the concordance rate is equal to or greater than a preliminarily set threshold value, the abnormal object detection section **454** detects the object as the abnormal object **7**. The abnormal object detection section **454** outputs the position, shape, and type of the detected abnormal object **7** as abnormal object information to the work status management section **452**.
(71) [Computation Section]
(72) The computation section **453** is electrically connected to the measured data processing section **451**, and obtains the tilting angle, position, orientation, and swing angle of the upper swing body **3**, postures of the respective parts of the working assembly, and computation result of the current terrain from the measured data processing section **451**. This computation section **453** also obtains whether the hydraulic excavator **1** is in the manned operation state or the unmanned automated operation state from the changeover switch **43**, and performs processes such as computation according to the manned operation state or the unmanned automated operation state.
(73) For example, when the hydraulic excavator **1** is in the unmanned automated operation state, the computation section **453** obtains the operation plan from the work status management section **452**, computes a target trajectory of the lower traveling body **4**, a target trajectory of the bucket distal end **27**, and target operating speeds of the respective actuators (the respective hydraulic cylinders **23** and the respective hydraulic motors **26**) based the obtained operation plan, and outputs the computed result to the work status management section **452**. Note that, the operation plan includes at least a ground contact position of the bucket distal end **27** on the current terrain.
(74) Specifically, the computation section **453**, based on the computation result obtained from the measured data processing section **451**, first computes a target trajectory of the lower traveling body **4** for moving the bucket distal end **27** from its current location to a location where it can be brought into contact with the ground at a specified position included in the operation plan. Next, the computation section **453** computes a target trajectory of the bucket distal end **27** up to when the bucket distal end **27** is moved to a ground contact position specified by the work status management section **452** and dirt is stored inside the bucket **22**.
(75) In addition, the computation section **453** computes each a target trajectory of the lower traveling body **4** and a target trajectory of the bucket distal end **27** until the hydraulic excavator **1** dumps dirt in the dumping site **50**. Note that, the computation section **453** creates the computed

target trajectory of the lower traveling body **4** and target trajectory of the bucket distal end **27** with the global coordinate system as reference. Further, the computation section **453**, based on the computed target trajectory of the lower traveling body **4** and target trajectory of the bucket distal end **27**, computes the target operating speeds of the respective actuators (the respective hydraulic cylinders **23** and the respective hydraulic motors **26**) required for operating the vehicle body. Then, the computation section **453** outputs the computed result to the work status management section **452**.

(76) On the other hand, when the hydraulic excavator **1** is in the manned operation state, the computation section **453** does not obtain the operation plan from the work status management section **452**, and does not perform the computation of the target trajectory of the lower traveling body **4**, the target trajectory of the bucket distal end **27**, or the target operating speeds of the respective actuators (the respective hydraulic cylinders **23** and the respective hydraulic motors **26**)

(77) [Work Status Management Section]

(78) The work status management section **452** selects a work content according to the work order in the work plan recorded in the work DB **456**, and creates the operation plan for the hydraulic excavator **1** based on the selected work content, the measurement result of the laser scanners **34**, and the like, so as to manage the work status of the hydraulic excavator **1**.

(79) Specifically, the work status management section **452** is electrically connected to each of the abnormal object detection section **454**, the work DB **456** and the measured data processing section **451**, and obtains the detection result (for example, the abnormal object information) from the abnormal object detection section **454**, the work plan from the work DB **456**, and the current terrain from the measured data processing section **451**. First, the work status management section **452**, based on the work plan obtained from the work DB **456**, selects a work content, for example, in sequence according to the work order in the work plan. Next, the work status management section **452** creates the operation plan including at least the ground contact position of the bucket distal end **27** regarding the selected work content.

(80) Next, the work status management section **452** outputs the created operation plan to the computation section **453**, and instructs the computation section **453** to compute the target trajectory of the bucket distal end **27**, the target trajectory of the lower traveling body **4**, and the target operating speeds of the respective actuators based on the operation plan. Next, the work status management section **452** obtains the computation results of the target trajectory of the bucket distal end **27**, the target trajectory of the lower traveling body **4**, and the target operating speeds of the respective actuators from the computation section **453**.

(81) In addition, the work status management section **452**, based on the detection result (for example, the abnormal object information) obtained from the abnormal object detection section **454**, and the target trajectory of the bucket distal end **27** and the target trajectory of the lower traveling body **4** obtained from the computation section **453**, determines whether or not the execution of the above-described operation plan is to be hindered by the presence of the abnormal object detected by the abnormal object detection section **454**.

(82) When there is no presence of an abnormal object that hinders any of the target trajectory of the bucket distal end **27** or the target trajectory of the lower traveling body **4** on the work site **5**, the work status management section **452** determines that the execution of the operation plan is not to be hindered by the presence of the abnormal object. At this time, the work status management section **452** outputs the target operating speeds of the respective actuators (the respective hydraulic cylinders **23** and the respective hydraulic motors **26**) obtained from the computation section **453** as work status management information to the vehicle body control section **411** in the vehicle body controller **41**. The work status management information here is namely a control signal.

(83) On the other hand, when there is a presence of an abnormal object that hinders at least one of the target trajectory of the bucket distal end **27** or the target trajectory of the lower traveling body **4** on the work site **5**, the work status management section **452** determines that the execution of the

operation plan is to be hindered by the presence of the abnormal object. At this time, the work status management section **452** instructs the vehicle body control section **411** to halt the work being executed. Next, the work status management section **452** further determines whether or not the halted work (that is, the hindered work) is dividable into a work executed in a "range including the abnormal object" and a work executed in a "range not including the abnormal object."

(84) When the halted work is determined to be dividable into a work executed in the "range including the abnormal object" and a work executed in the "range not including the abnormal object," the work status management section **452** selects a work content in the "range not including the abnormal object," creates a new work plan in the "range not including the abnormal object," and adds the new work plan to the work DB **456**. After that, the work status management section **452** outputs the ground contact position of the bucket distal end **27** in the "range not including the abnormal object" as a new operation plan to the computation section **453**, and instructs the computation section **453** to compute the target trajectory of the bucket distal end **27**, the target trajectory of the lower traveling body **4**, and the target operating speeds of the respective actuators based on the operation plan. In other words, the work status management section **452** demands the computation section **453** to compute the target trajectory of the bucket distal end **27**, the target trajectory of the lower traveling body **4**, and the target operating speeds of the respective actuators (the respective hydraulic cylinders **23**, and the respective hydraulic motors **26**) for executing the work in the "range not including the abnormal object."

(85) Note that, when there does not exist a work that is executable in the work plan recorded in the work DB **456**, the work status management section **452** instructs the vehicle body control section **411** to terminate the work.

(86) In the following, based on FIG. **5** to FIG. **7**, an example of dividing an excavation area into a "range including the abnormal object **7**" and a "range not including the abnormal object **7**" on the work site **5** where the abnormal object **7** has been detected will be described in detail.

(87) FIG. **5** to FIG. **7** illustrates an "excavation area i" where the abnormal object **7** has been detected by the abnormal object detection section **454**. In FIG. **5** to FIG. **7**, by setting a certain point on the work site **5** as the base point, a coordinate system unique to the site in an XYZ space in the illustrated direction is defined, and the respective computation results of the measured data processing section **451** and the respective target trajectories computed by the computation section **453** used in the global coordinate system are each converted to the coordinate system unique to the site.

(88) FIG. **5** is a plan view of the work site **5**, and FIG. **6** and FIG. **7** are side views of the work site **5** along the arrow head in FIG. **5**. As illustrated in FIG. **6** and FIG. **7**, the current terrain of the "excavation area i" is constituted of an inclined surface **72** and a planar surface **73**. In the present embodiment, the abnormal object **7** is assumed to be exposed from the inclined surface **72** when the work is started. As illustrated in FIG. **6**, in the "excavation area i," excavation until a depth indicated in the designed terrain **6** is executed by the hydraulic excavator **1**.

(89) As illustrated in FIG. **5** to FIG. **7**, the target trajectory (see dashed line portion in the drawings) of the bucket distal end **27** computed by the computation section **453** in the "excavation area i" overlaps with the position of the abnormal object **7**, and the hydraulic excavator **1** is in a state unable to continue the work. Note that, the abnormal object **7** in the present embodiment refers to a thing (for example, a large stone) having a size to the extent of hindering the work of the hydraulic excavator **1**, and therefore, even if an abnormal object like a stone that is comparatively small is detected, it does not actually become a hinderance to the work.

(90) In the present embodiment, even when the work cannot be continued because of the abnormal object **7** present on the target trajectory computed by the computation section **453** in the "excavation area **1**," the work status management section **452** further divides the "excavation area i" into an "excavation area i_**1**" as the "range including the abnormal object **7**" and the "excavation area i_**2**" as the "range not including the abnormal object **7**," and by commanding the work status

management information in the “range not including the abnormal object **7**” to the vehicle body control section **411**, the work by the hydraulic excavator **1** can be continued.
(91) [Vehicle Body Control Section]
(92) The vehicle body control section **411** controls the operation of the hydraulic excavator **1** based on the operation plan created by the work status management section **452**. As illustrated in FIG. **4**, the vehicle body control section **411** is electrically connected to the changeover switch **43**, and obtains whether the hydraulic excavator **1** is in the manned operation state or the unmanned automated operation state from the changeover switch **43**. The vehicle body control section **411** is also electrically connected to the work status management section **452** and obtains the above-described work status management information from the work status management section **452**.
(93) When the hydraulic excavator **1** is in the manned operation state, the vehicle body control section **411** drives the control valve **40** to operate the respective actuators according to the operation amount of the control lever **30**. On the other hand, when the hydraulic excavator **1** is in the unmanned automated operation state, the vehicle body control section **411** drives the control valve **40** to operate the respective actuators according to the target operating speeds of the respective actuators obtained from the work status management section **452** as the work status management information. When the termination of all the works is output from the work status management section **452**, the vehicle body control section **411** immediately stops the operation of the hydraulic excavator **1** or moves the hydraulic excavator **1** to a preliminarily specified position and then stops its operation. Note that, when the termination of all the works is output from the work status management section **452**, the vehicle body control section **411** may output the fact that the work plan has terminated on the monitor **42**.
(94) In the following, the control process of the automated work system **10** will be described with reference to FIG. **8** and FIG. **9**. FIG. **8** is a flowchart indicating step S**10** to step S**21** of the control process, and FIG. **9** is a flowchart indicating step S**22** to step S**27** of the control process.
(95) First, in step S**10**, a work ID number (work i) is assigned. Here, “i” is 51, for example.
(96) In step S**11** following step S**10**, the work status management section **452** obtains information on “work i” from the work plan recorded in the work DB **456**. Specifically, the work status management section **452** obtains an “excavation area ID,” a “work status,” a “remaining work amount,” and a “work amount” regarding the work whose work ID is “work i.”
(97) In step S**12** following step S**11**, the work status management section **452** outputs information on the “excavation area i” from the obtained information on “work i” to the computation section **453**. Specifically, the work status management section **452** outputs a designed terrain associated with the “excavation area i” to the computation section **453**. The designed terrain associated with the “excavation area i” is a three-dimensional terrain shape desired to be created by the excavation of the hydraulic excavator **1** from now.
(98) In step S**13** following step S**12**, the work status management section **452** first outputs the created operation plan to the computation section **453**, and instructs the computation section **453** to compute the target trajectory of the bucket distal end **27**, the target trajectory of the lower traveling body **4**, and the target operating speeds of the respective actuators (the respective hydraulic cylinders **23** and the respective hydraulic motors **26**) based on the operation plan. Next, the computation section **453** computes each of the target trajectory of the bucket distal end **27**, the target trajectory of the lower traveling body **4**, and the target operating speeds of the respective actuators based on the operation plan and outputs the computed result, to the work status management section **452**, Accordingly, the work status management section **452** obtains the above-described computation result.
(99) In step S**14** following step S**13**, the work status management section **452** obtains the abnormal object information from the abnormal object detection section **454**. In step S**15** following step S**14**, the work status management section **452** determines whether or not an abnormal object that is to hinder the operation plan of the “work I” is present. At this time, the work status management

section **452**, based on a three-dimensional target trajectory of the vehicle body, such as the target trajectory of the bucket distal end **27** and the travel trajectory of the lower traveling body **4** obtained in step S**13** and the abnormal object information obtained in step S**14**, determines whether or not the object (namely, the abnormal object) described in the abnormal object information is present on the three-dimensional target trajectory of the vehicle body.
(100) When an abnormal object is determined to be present on the three-dimensional target trajectory of the vehicle body, the control process proceeds to step S**22**. For example, as the work site **5** illustrated in FIG. **5**, when the abnormal object **7** is present on the target trajectory of the bucket distal end **27** in the site coordinate system unique to the site, the control process proceeds to step S**22**. On the other hand, when an abnormal object is determined not to be present on the three-dimensional target trajectory of the vehicle body, the control process proceeds to step S**16**.
(101) In step S**16**, the work status management section **452** outputs the work status management information to the vehicle body control section **411**. Specifically, the work status management section **452** outputs the target operating speeds of the respective actuators obtained in step S**13** to the vehicle body control section **411**. Then, the vehicle body control section **411** causes the respective actuators to operate according to the target operating speeds of the respective actuators. Accordingly, the hydraulic excavator **1** performs the work by automated operation.
(102) In step S**17** following step S**16**, the work status management section **452** calculates the “remaining work amount” of the “work i” and updates the work DB **456**. Specifically, the work status management section **452** calculates the “progress status” of the “work i” from the difference between the designed terrain of the “excavation area i” recorded in the work DB **456** and the three-dimensional information on the current terrain obtained from the measured data processing section **451**, and updates the “remaining work amount” of the “work i” recorded in the work DB.
(103) In step S**18** following step S**17**, the work status management section **452** determines whether or not the “remaining work amount” of the “work i” calculated in step S**17** has reached 0%. When the “remaining work amount” is determined to have reached 0%, the control process proceeds to step S**19**, On the other hand, when the “remaining work amount” is determined not to have reached 0%, the control process returns to step S**11**.
(104) In step S**19**, the work status management section **452** updates the “work status” of the “work i” recorded in the work DB **456** to “completed.”
(105) In step S**20** following step S**19**, the work status management section **452** determines whether or not a work whose “work status” is “not yet started” exists in the work plan stored in the work DB **456**. When a work that is “not yet started” is determined to be present, the control process proceeds to step S**21**. In step S**21**, it is updated as “i=i+1” (that is, i=52). After that, the control process returns to step S**11**. On the other hand, when a work whose “work status” is “not yet started” is determined not to be present, the work status management section **452** instructs the termination of all the works to the vehicle body control section **411**. Accordingly, one sequence of the control process is terminated.
(106) As described above, when an abnormal object is determined to be present in step S**15**, the control process proceeds to step S**22**. In step S**22**, the work status management section **452** determines whether or not the “excavation area i” is dividable into a “range in which a hinderance element is present” (that is, the range including an abnormal object) and a “range in which a hinderance element is not present” (that is, the range not including an abnormal object). Specifically, the work status management section **452** determines whether or not the “excavation area i” of the “work i” illustrated in FIG. **6** recorded in the work DB **456** into the “excavation area i_**1**” as the “range including the abnormal object **7**” and the “excavation area i_**2**” as the “range not including the abnormal object **7**” as illustrated in FIG. **7**.
(107) For example, in the example illustrated in FIG. **7**, since the abnormal object **7** has been excavated from the inclined surface **72** of the work site **5**, the work status management section **452** divides the “excavation area i” into the inclined surface **72** portion as the “excavation area i_**1**” and

the planar surface **73** portion as the "excavation area i_**2**" respectively along the Y-axis direction. The "excavation area i_**1**" as the "range including the abnormal object **7**" is cut out as a rectangular range shape having a "constant margin" with respect to the abnormal object **7** on the X-Y coordinate illustrated in FIG. **5**, The "constant margin" may be determined based on the type of the abnormal object **7** described in the abnormal object information, or may be preliminarily determined as a constant value in common between all the abnormal objects **7**. As a result of cutting out the "excavation area i_**1**" from the "excavation area i," the "excavation area i_**2**" as the "range not including the abnormal object **7**" is generated in the range illustrated in FIG. **5** and FIG. **7**.
(108) Note that, regarding the determination of whether or not the "excavation area i" is dividable into the "excavation area i_**1**" and "excavation area i_**2**," for example, a threshold value is preliminarily determined based on the "work amount," and the "excavation area i" is determined to be dividable when the "excavation area i_**2**" is equal to or greater than the threshold value, and the "excavation area i" is determined to be undividable when the "excavation area i_**2**" is smaller than the threshold value.
(109) When the "excavation area i" is determined to be undividable in step S**22**, the process proceeds to step S**23**. In step S**23**, the work status management section **452** changes the "work status" of the "work i" to "halted." After that, the control process returns to step S**20**.
(110) On the other hand, when the "excavation area i" is determined to be dividable in step S**22**, the control process proceeds to step S**24**, In step S**24**, with respect to the "excavation area i" of the "work i" recorded in the work DB **456**, the work status management section **452** assigns an excavation area ID named "excavation area i_**1**" to the "range in which a hinderance element is present" and an excavation area ID named "excavation area i_**2**" to the "range in which a hinderance element is not present," respectively, That is, the work status management section **452** assigns the excavation area ID named "excavation area i_**1**" to the "range including the abnormal object **7**" and the excavation area. ID named "excavation area i_**2**" to the "range not including the abnormal object **7**," respectively.
(111) In the process here, as indicated in Table 2 below, for example, when the "excavation area **52**" is determined to be dividable into an "excavation area **52_1**" and an "excavation area **52_2**," the work status management section **452** assigns an excavation area. ID "excavation area **52_1**" to the "range including the abnormal object **7**" and an excavation area ID "excavation area **52_2**" to the "range not including the abnormal object **7**," respectively.
(112) In step S**25** following step S**24**, the work status management section **452** updates the work ID of the "work i" to "work i_**1**" and the excavation area ID to "excavation area i_**1**," and changes the work status to "halted" recorded in the work DB **456**. In the process here, as indicated in Table 2 below, for example, the work status management section **452** updates the work ID of the "work **52**" recorded in the work DB **456** to a "work **52_1**" and the excavation area ID to "excavation area **52_1**" and changes the work status to "halted."
(113) In step S**26** following step S**25**, the work status management section **452** adds "work i_**2**" to the work ID, "excavation area i_**2**" to the excavation area ID, and "not yet started" to the work status, respectively, of the work DB **456**. In the process here, as indicated in Table 2 described below, for example, the work status management section **452** adds "work **52_2**" to the work ID, "excavation area **52_2**" to the excavation area ID, and "not yet started" to the work status, respectively, of the work DB **456**.
(114) TABLE-US-00002 TABLE 2 Remaining Excavation Area Work Work Work ID ID Work Status Amount Amount Work 51 Excavation Area 51 Completed 0% 1000 Work Excavation Area Halted 30% 500 52_1 52_1 Work Excavation Area Not Yet Started 100% 1500 52_2 52_2 Work 53 Excavation Area 53 Not Yet Started 100% 3000 Work 54 Excavation Area 54 Not Yet Started 100% 1500 . . . .
(115) In step S**27** following step S**26**, the work ID number (work i) is updated to "i_**2**." After that,

the process returns to step S**11**.

(116) In the automated work system **10** of the present embodiment, when the abnormal object **7** is detected, the work status management section **452** determines whether or not the execution of the operation plan is to be hindered by the presence of the abnormal object **7**, and when the execution of the operation plan is determined to be hindered by the presence of the abnormal object **7**, the work status management section **452** further determines whether or not the "excavation area i" is dividable into the "range including the abnormal object **7**" and the "range not including the abnormal object **7**." When the "excavation area i" is determined to be dividable, the work status management section **452** selects a work in the "range not including the abnormal object **7**," creates an operation plan of the selected work, and causes the work of the hydraulic excavator **1** by automated operation to continue. Accordingly, even when the abnormal object **7** that is to hinder the work of the hydraulic excavator **1** appears on the work site **5**, the work status management section **452** selects another work that is executable (that is, a work in the "range not including the abnormal object **7**") to allow continuation of work by automated operation without needing a handling by the operator, and thus a decrease in productivity can be avoided.

Second Embodiment

(117) In the following, an automated work system of the second embodiment will be described with reference to FIG. **8**, FIG. **10**, and FIG. **11**, While the automated work system of the present embodiment has a configuration similar to that of the first embodiment, it is unlike the first embodiment in the control process. In the following, only the differences from the first embodiment will be described.

(118) That is, in the present embodiment, when the abnormal object **7** that is to hinder the work of the hydraulic excavator **1** is present on the work site **5**, the content of the work to be executed by the hydraulic excavator **1** is determined by a selecting operation of the work administrator. In addition, after receiving approval of the work administrator, the work status management section **452** outputs work status management information for continuing the work in the "range not including the abnormal object **7**" to the vehicle body control section **411**. In addition, according to the selecting operation of the work administrator, the unmanned automated operation state of the hydraulic excavator **1** is switched to the manned operation state. Further, by the hydraulic excavator **1** being switched from the manned operation state to the unmanned automated operation after the abnormal object **7** has been removed from the work site **5** by the work administrator, the work of the hydraulic excavator **1** by automated operation is continued.

(119) The work administrator can by anyone who has acquired the usage of the monitor **42** and the changeover switch **43**. In addition, the work administrator may be present in the cab in the upper swing body **3** or in any place inside/outside of the work site **5** that allows monitoring the work of the hydraulic excavator **1**. Further, the monitor **42** and the changeover switch **43** may be arranged in any place where they can be visually perceived and operated by the work administrator.

(120) In the control process of the automated work system of the second embodiment, step S**10** to step S**27** are the same as those in the first embodiment, and step S**28** to step S**37** are newly added processes. In the following, only the newly added step S**28** to step S**37** will be described based on FIG. **10**, In addition, in the present embodiment, the abnormal object detection section **454** determines whether or not a human is present around the hydraulic excavator **1** based on the measurement results of the laser scanners **34**, and when a human is determined to be present, outputs the fact to the work status management section **452**.

(121) As indicated in FIG. **10**, when the "excavation area i" is determined to be undividable into the "range in which a hinderance element is present" and the "range in which a hinderance element is not present" in step S**22**, the control process proceeds to step S**23** similarly to the first embodiment, and the "work status" of the "work i" is changed to "halted." After that, the control process returns to step S**20**.

(122) On the other hand, when the "excavation area i" is determined to be dividable into the "range

in which a hinderance element is present" and the "range in which a hinderance element is not present" in step S**22**, the control process proceeds to step S**28**. In step S**28**, the work status management section **452** displays the abnormal object information regarding the abnormal object **7** that is to hinder the work on the monitor **42** as indicated in FIG. **11**, and thereby notifies the work administrator of the appearance of the abnormal object **7**. Further, the work status management section **452** displays the "excavation area i_**1**" as the "range including the abnormal object **7**" and the "excavation area i_**2**" as the "range not including the abnormal object **7**" on the monitor **42** as indicated in FIG. **11** on the monitor **42**, and thereby notifies the work administrator of the fact that the "excavation area i" is dividable into the "excavation area i_**1**" and the "excavation area i_**2**."

(123) In step S**29** following step S**28**, the work administrator selects whether or not to continue the work in the divided "excavation area i_**2**" via the monitor **42** (see FIG. **11**). When it is selected by the work administrator to continue the work, the control process proceeds to the above-described step S**24**. On the other hand, when it is selected not to continue the work, the process proceeds to step S**30**.

(124) In step S**30**, the work administrator selects whether or not to eliminate the abnormal object **7** from the work site **5** via the monitor **42** (see FIG. **11**). When it is selected not to eliminate the abnormal object, the control process proceeds to the above-described step S**23**. On the other hand, when it is selected by the work administrator to eliminate the abnormal object, the control process proceeds to step S**31**.

(125) In step S**31**, the work administrator operates the changeover switch **43** to switch the hydraulic excavator **1** from the unmanned automated operation state to the manned operation state. In step S**32** following step S**31**, the work status management section **452** issues a release password of the manned operation state and notifies the work administrator of the release password via the monitor **42**.

(126) In step S**33** following step S**32**, the work administrator eliminates the abnormal object **7** from the work site **5**. As a method to eliminate the abnormal object **7** from the work site **5**, the work administrator may operate the hydraulic excavator **1** by operating the control lever **30**, or may be performed by hand work of the work administrator.

(127) In step S**34** following step S**33**, the work administrator inputs the release password of the manned operation state into the monitor **42** and operates the changeover switch **43**. In step S**35** followed by step S**34**, the work status management section **452** determines whether or not a human is present around the hydraulic excavator **1** based on the result from the abnormal object detection section **454**. When a human is determined to be present, the process proceeds to step S**36**. In step S**36**, the work status management section **452** advises the work administrator via the monitor **42** to evacuate the human from around the hydraulic excavator **1** on the monitor **42**. After that, the control process returns to step S**34**.

(128) On the other hand, when a human is determined not to be present in the surroundings in step S**35**, the control process proceeds to step S**37**. In step S**37**, the changeover switch **43** switches the hydraulic excavator **1** from the manned operation state to the unmanned automated operation state. After that, the control process returns to the above-described step S**17**, and the work of the hydraulic excavator **1** by automated operation is continued.

(129) With the automated work system of the present embodiment, operational advantages similar to those of the above-described first embodiment can be obtained and the following operational advantages are further obtained. That is, when the excavation area is determined to be dividable into the "range including the abnormal object" and the "range not including the abnormal object," in a case where, after the work administrator switches the hydraulic excavator **1** from the unmanned automated operation state to the manned operation state and removes the abnormal object **7** from the work site **5**, an instruction for starting the work of the hydraulic excavator **1** is given by the work administrator and a human is not detected around the hydraulic excavator **1**, the work status management section **452** selects another work in the work plan and thereby

continuation of work by automated operation becomes possible. Accordingly, the work plan described in the work DB **456** can be completely executed and thereby a decrease in productivity can be further avoided.

Third Embodiment

(130) FIG. **12** is a block diagram illustrating a configuration of an automated work system according to the third embodiment. While an automated work system **100** of the present embodiment is unlike the above-described first embodiment in that an object DB **461** and a work DB **462** are disposed in a server **46**, the other configurations are similar to those in the first embodiment.

(131) As illustrated in FIG. **12**, in the automated work system **10**A of the present embodiment, the object DB **461** and the work DB **462** are independent from an automated operation controller **45**A, and disposed in the server **46**. The server **46** is, for example, arranged in a management center and is configured to be capable of communicating with the automated operation controller **45**. Note that, the object DB **461** has a structure similar to that of the object DB **455** in the first embodiment, and the work DB **462** has a structure similar to that of the work DB **456** in the first embodiment.

(132) With the automated work system **10**A of the present embodiment, operational advantages similar to those of the above-described first embodiment can be obtained, and also, since the object DB **461** and the work DB **462** are disposed in the server **46**, compactification of the automated operation controller **45**A can be achieved.

(133) Note that, while the embodiments indicated up to the present have assumed a situation in which an abnormal object is exposed from the excavation area at the start of work, the automated work system is also applicable to a situation in which an abnormal object is excavated during the excavation by the hydraulic excavator. In addition, while a hydraulic excavator with control levers being mounted inside the work machine has been described, the automated work system is also applicable to a hydraulic excavator with control levers being disposed inside a remote operation room separately from the hydraulic excavator to allow remote operation.

(134) While embodiments of the present invention have been described in detail above, the present invention is not limited to the above-described embodiments, and can be subjected to various kinds of changes of design without departing from the spirit of the present invention described in the appended claims.

REFERENCE SIGNS LIST

(135) **1** Hydraulic excavator **2** Working assembly **3** Upper swing body **4** Lower traveling body **10**, **10**A Automated work system **28***a* Vehicle body IMU **28***b* Boom IMU **28***c* Arm IMU **28***d* Bucket IMU **30** Control lever **31***a*, **31***b* GNSS antenna **32** GNSS controller **33** Swing angle sensor **34** Laser scanner (surrounding environment measuring device) **39** Shut-off valve **40** Control valve **41** Vehicle body controller **42** Monitor (information input device, information display device) **43** Changeover switch **45**, **45**A Automated operation controller (automated operation controlling device) **46** Server **411** Vehicle body control section **451** Measured data processing section **452** Work status management section **453** Computation section **454** Abnormal object detection section **455** Object DB (object recording section) **456** Work DB (work recording section) **461** Object DB **462** Work DB

Claims

1. An automated work system comprising: a surrounding environment measuring device that measures a surrounding environment of a work machine; and an automated operation controlling device that controls an automated operation of the work machine, wherein the automated operation controlling device includes: a work status management section that selects, according to a work order in a work plan obtained, a work content from the work plan, creates an operation plan for the work machine on a work site based on the selected work content and information on the

surrounding environment measured by the surrounding environment measuring device, and outputs a control signal to a vehicle body controller disposed in the work machine based on the created operation plan, so as to manage a work status of the work machine; and an abnormal object detection section that detects an abnormal object present on the work site where the work plan is executed based on the information on the surrounding environment measured by the surrounding environment measuring device, and when an abnormal object is detected by the abnormal object detection section on the work site, the work status management section determines whether or not an execution of the operation plan is to be hindered by the presence of the abnormal object, and when the execution of the operation plan is determined to be hindered by the presence of the abnormal object, further determines whether or not a hindered work is dividable into a work executed in a range including the abnormal object and a work executed in a range not including the abnormal object by comparing a work amount in the range not including the abnormal object with a preliminarily determined threshold value, and when the hindered work is determined to be dividable, creates the operation plan for the range not including the abnormal object.

2. The automated work system according to claim 1, wherein the work machine includes a traveling body and a working assembly, the automated operation controlling device further includes a computation section that computes a target trajectory of a distal end of the working assembly and a target trajectory of the traveling body based on the operation plan, and when the abnormal object that hinders at least one of the target trajectory of the distal end of the working assembly or the target trajectory of the traveling body computed by the computation section is present, the work status management section determines that the execution of the operation plan is to be hindered by the presence of the abnormal object.

3. The automated work system according to claim 1, further comprising an object recording section that records at least one of information on a predicted present object predicted to be present on the work site or information on an unpredicted present object other than the predicted present object, wherein the object recording section is disposed in the automated operation controlling device or a server.

4. The automated work system according to claim 3, wherein the abnormal object detection section detects an abnormal object present on the work site based on a concordance rate of the information on the surrounding environment measured by the surrounding environment measuring device and the information on an object recorded in the object recording section.

5. The automated work system according to claim 1, further comprising a work recording section that records the work plan, wherein the work plan includes a work content and a work order executed by at least one work machine, and the work recording section is disposed in the automated operation controlling device or a server.

6. The automated work system according to claim 1 further comprising an information display device that displays the work content selected by the work status management section, an executing range of the work, and the information on the abnormal object that is to hinder the execution of the operation plan.

7. The automated work system according to claim 6, further comprising an information input device that accepts input from at least a work administrator, wherein, when the execution of the operation plan is determined to be hindered by the presence of the abnormal object, and continuation of work is instructed by the input to the information input device by the work administrator, the work status management section creates a work plan for the range not including the abnormal object.

8. The automated work system according to claim 7, wherein after the work machine is switched to manual control by the work administrator and the abnormal object is removed from the work site, and when an instruction for starting work of the work machine is given by the work administrator and a human is not detected around the work machine based on the information on the surrounding

environment measured by the surrounding environment measuring device, the work status management section selects another work from the work plan.