United States Patent Application Publication	20250257549
Kind Code	A1
Publication Date	August 14, 2025
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AUTOMATIC DRIVING SYSTEM FOR WORK MACHINE

Abstract

An automatic operation system providing high followability to a target speed, includes a map generation part, a map complementation part and a manipulated variable output part. The map generation part generates a map indicating the relationship between a motion speed of a work device and a manipulated variable detected by a manipulated-variable detection device. The map complementation part complements the map, when the maximum value of the manipulated variable of the map is less than the maximum manipulated variable, to render the maximum value equal to the maximum manipulated variable. The manipulated variable output part generates the manipulated variable for automatic operation based on the target speed and the complemented map and inputs the manipulated variable to a driving device.

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Appl. No.:	**18/702421**
Filed (or PCT Filed):	**October 11, 2022**
PCT No.:	**PCT/JP2022/037935**

Foreign Application Priority Data

JP	2021-179517	Nov. 02, 2021

Publication Classification

Int. Cl.: **E02F9/20** (20060101); **E02F3/43** (20060101)

U.S. Cl.:

CPC **E02F9/205** (20130101); **E02F3/439** (20130101); **E02F9/2045** (20130101);

Background/Summary

TECHNICAL FIELD
[0001] The present invention relates to a system for performing an automatic operation of a work machine.
BACKGROUND ART
[0002] In Patent Document 1 is described an apparatus for performing an automatic operation of a hydraulic work machine. The apparatus includes a mode selection means of switching the driving mode between a teaching mode and an automatic operation mode. In the teaching mode, the supply flow rate to the hydraulic driving device is stored in time series. In the automatic operation mode, the opening degree of the control valve to provide a target value, which is the supply flow rate stored in time series, is calculated, and a command with respect to the opening degree is input to the control valve.
[0003] According to the apparatus, in which the manipulated variable (opening command in the above document 1) is calculated by use of the supply flow rate stored in time series as the target value, it is not possible to input such a manipulated variable to the control valve as to render the actual supply flow rate larger than the amount stored in time series. This may hinder the actual speed of the work machine from being made close to the target speed when the actual speed falls below the target speed to thereby disable the attachment from being operated in accordance with the target speed. This problem may occur also when a manipulated variable is input to an element other than the control valve.
CITATION LIST
Patent Literature
[0004] Patent Literature 1: Japanese Unexamined Patent Publication No. Hei 11-181820
SUMMARY OF INVENTION
[0005] It is an object of the present invention to provide a system for performing an automatic operation of a work machine, the system being capable of making the speed of the motion of a work device of the work machine quickly follow a target speed.
[0006] Provided is a system for performing an automatic operation of a work machine that includes a machine body, a work device, an operation part, and a driving device. The system includes a manipulated-variable detection device, a speed information acquisition device, a map generation part, a map complementation part, a target speed generation part, and a manipulated-variable input part. The work device is attached to the machine body capably of performing a work motion. The driving device allows a manipulated variable to be input to the driving device, and makes the work device perform the work motion in accordance with the manipulated variable. The operation part allows a work operation for operating the work device to be applied to the operation part, and inputs the manipulated variable corresponding to the work operation to the driving device. The manipulated-variable detection device detects the manipulated variable that is input from the operation part to the driving device. The speed information acquisition device acquires speed information on a motion speed of the work device. The map generation part generates a map based on the manipulated variable detected by the manipulated-variable detection device and the speed information acquired by the speed information acquisition device. The map defines a relationship

between the manipulated variable and the motion speed of the work device. When a maximum value of the manipulated variable included in the map generated by the map generation part is smaller than a preset maximum manipulated variable, the map complementation part complements the map so as to render the maximum value of the manipulated variable of the map equal to the maximum manipulated variable. The target speed generation part generates a target speed that is a target value of the motion speed for an automatic operation of the work machine. The manipulated-variable input part generates the manipulated variable for making the work device perform the work motion at the target speed based on the target speed generated by the target speed generation part and the map complemented by the map complementation part, and inputs the manipulated variable to the driving device.

Description

BRIEF DESCRIPTION OF DRAWINGS
[0007] FIG. **1** is a side view of a work machine according to an embodiment of the present invention.
[0008] FIG. **2** is a block diagram showing components of the work machine and a system for the automatic operation thereof.
[0009] FIG. **3** is a side view showing a target trajectory of the tip of a bucket of the work machine.
[0010] FIG. **4** is a diagram showing a map generated and complemented in the automatic operation system.
[0011] FIG. **5** is a flowchart showing arithmetic control operations performed for generating and complementing the map.
[0012] FIG. **6** is a flowchart showing arithmetic control operations that is performed for the automatic operation of the work machine based on the complemented map.
DETAILED DESCRIPTION
[0013] A preferred embodiment of the present invention will be described with reference to FIGS. **1** to **6**.
[0014] FIG. **1** shows a work machine **10** according to the embodiment.
[0015] The work machine **10** is a machine for performing work, and an automatic operation of the work machine **10** can be performed by an automatic operation system shown in FIG. **2**. As well as the automatic operation, the work machine **10** can be also manually operated by an operator's operation. The work machine **10** may be either operated by an operator getting on the work machine **10** or remotely controlled from the outside of the work machine **10**. The work machine **10** is, for example, a construction machine for performing construction work. The work machine **10** shown in FIG. **1** is an excavator. The work machine to which the automatic operation system according to the present invention is applied, however, may be a work machine other than an excavator, such as a crane.
[0016] The work machine **10** includes a machine body **12**, an attachment **15**, a driving device and an operation part **21**, the driving device including a plurality of actuators **17** and a drive control part **19** shown in FIG. **2**.
[0017] The machine body **12** is the main body of the work machine **10**. The machine body **12** includes a lower traveling body **11** and an upper turning body **13**.
[0018] The lower traveling body **11** is capable of performing a traveling motion, which causes the work machine **10** to travel on the ground. The lower traveling body **11** includes a traveling device, for example, a pair of crawlers.
[0019] The upper turning body **13** is mounted on the lower traveling body **11** capably of turning. The upper turning body **13** includes a cab **13***a*. The cab **13***a* allows an operator to make operations for the work machine **10** in the cab **13***a*.

[0020] The attachment **15** is a work device capable of performing work motions. The attachment **15** shown in FIG. **1** includes a boom **15***b*, an arm **15***c*, and a tip attachment **15***d*. The boom **15***b* is attached to the upper turning body **13** capably of performing a rising and falling motions, that is, vertically rotational movement, with respect to the upper turning body **13**. The arm **15***c* is connected to the boom **15***b* capably of vertically rotational movement with respect to the boom **15***b*. The tip attachment **15***d* is attached to the arm **15***c* capably of vertically rotational movement to form the tip of the attachment **15**. The tip attachment **15***d* shown in FIG. **1** is a bucket that scoops earth and sand. Alternatively, the tip attachment **15***d* may be either a device that pinches objects, such as a grapple, or a device that crushes objects, such as a breaker. Any part of the attachment **15**, which is the work device, can be specified as the control target part **15***c*. According to the example shown in FIG. **1**, the tip of the tip attachment **15***d*, that is, the tip of the bucket, is specified as the control target part **15***c*. The control target part **15***e* may be another part, for example, the tip of the arm **15***c*.

[0021] The attachment **15** is capable of performing a plurality of types of motions as the work motions. The plurality of types of motions include rotational movement of the boom **15***b* with respect to the upper turning body **13**, specifically, a boom rising motion and a boom falling motion. The boom rising motion is an upward (clockwise direction in FIG. **1**) rotational movement of the boom **15***b* with respect to the upper turning body **13**, and the boom falling motion is a downward (counterclockwise in FIG. **1**) rotational movement of the boom **15***b* with respect to the upper turning body **13**. The plurality of types of motions include vertically rotational movement of the arm **15***c* with respect to the boom **15***b*, specifically, an arm crowd motion and an arm damp motion. The arm crowd motion is a rotational movement of the arm **15***c* with respect to the boom **15***b* in a direction in which the tip of the arm **15***c* approaches the boom **15***b* (counterclockwise in FIG. **1**), and the arm damp motion is a rotational movement of the arm **15***c* with respect to the boom **15***b* in a direction in which the tip of the arm **15***c* approaches the boom **15***b* (clockwise in FIG. **1**). The plurality of motions include a vertically rotational movement of the tip attachment **15***d* with respect to the arm **15***c*, specifically, a first tip attachment motion and a second tip attachment motion. The first tip attachment motion is a rotational movement of the tip attachment **15***d* with respect to the arm **15***c* in a direction in which the tip of the tip attachment **15***d* approaches the arm **15***c* (counterclockwise in FIG. **1**), and the second tip attachment motion is a rotational movement of the tip attachment **15***d* with respect to the arm **15***c* in a direction in which the tip of the tip attachment **15***d* goes away from the arm **15***c* (counterclockwise in FIG. **1**). Since the tip attachment **15***d* illustrated in FIG. **1** is the bucket, the first and second tip attachment motions are also referred to as a bucket excavation motion and a bucket dump motion, respectively. The plurality of types of motions include turning motions of turning integrally with the upper turning body **13** with respect to the lower traveling body **11**, specifically, a right turning motion and a left turning motion.

[0022] The driving device allows a manipulated variable MV to be input to the driving device, and drives the attachment **15** so as to make the attachment **15** perform a motion corresponding to the thus input manipulated variable MV.

[0023] The plurality of actuators **17** are disposed at respective appropriate positions in the work machine **10** and driven by drive energy that is supplied from the drive control part **19** so as to make the attachment **15** perform the plurality of types of motions, respectively. As the plurality of actuators **17**, the driving device according to the present embodiment includes a plurality of hydraulic actuators, namely, a turning motor **17***a*, a boom cylinder **17***b*, an arm cylinder **17***c* and a tip attachment cylinder **17***d* shown in FIG. **1**, which are driven by the supply of hydraulic fluid.

[0024] The turning motor **17***a*, which is a hydraulic motor, turns the upper turning body **13** with respect to the lower traveling body **11** to thereby make the attachment **15** perform the turning motion. The turning motor **17***a*, alternatively, may be an electric motor that is driven by the supply of electric power.

[0025] Each of the boom cylinder **17***b*, the arm cylinder **17***c*, and the tip attachment cylinder **17***d* is a hydraulic cylinder. The boom cylinder **17**_b_ performs expansion and contraction motions with respect to the upper turning body **13** so as to make the boom **15**_b_ perform the rising and falling motions. The arm cylinder **17**_c_ performs expansion and contraction motions so as to move the arm **15**_c_ vertically rotationally with respect to the boom **15**_b_. The tip attachment cylinder **17**_d_ performs expansion and contraction motions so as to move the tip attachment **15**_d_ vertically rotationally with respect to the arm **15**_c_. In the case where the tip attachment **15**_d_ includes a movable part, such as a device for pinching an object, the driving device may further include an actuator for actuating the movable part.

[0026] The drive control part **19** supplies drive energy (supplies hydraulic fluid in the present embodiment) to the plurality of actuators **17** to operate the plurality of actuators **17**, and controls the movements of the plurality of actuators **17** so as to make the attachment **15** performs a motion corresponding to the manipulated variable MV that is input to the drive control part **19**. The drive control part **19**, thus, controls the drive of the attachment **15** by the plurality of actuators **17**, based on the manipulated variable MV that is input to the drive control part **19**. The drive control part **19** illustrated in FIG. **1** includes a hydraulic circuit for supplying hydraulic fluid to the plurality of actuators (hydraulic actuators) **17**. In the case where the plurality of actuators **17** include an electric actuator, the drive control part **19** may include an electric circuit for supplying electric power to the electric actuator. The drive control part **19** controls the motion of the attachment **15** by changing respective directions and speeds of the actions of the actuators **17**.

[0027] The drive control part **19** illustrated in FIG. **2** includes a hydraulic pump **19**_a_ and a plurality of control valves **19**_c_.

[0028] The hydraulic pump **19**_a_ discharges hydraulic fluid for operating the plurality of actuators **17**.

[0029] The plurality of control valves **19**_c_ are interposed between the hydraulic pump **19**_a_ and the plurality of actuators **17**, respectively. Each of the control valves **19**_c_ makes a valve opening action so as to control the direction and speed of the operation of the corresponding actuator **17** among the plurality of actuators **17**. Specifically, the control valve **19**_c_ is composed of a pilot-operated hydraulic selector valve, which is opened by the input of a pilot pressure thereto as the manipulated variable MV, by a stroke corresponding to the pilot pressure, to thereby make the direction and flow rate of hydraulic fluid supplied from the pump **19**_a_ to the actuator **17** correspond to the manipulated variable MV.

[0030] The operation part **21** allows an operator to apply a plurality of types of work motions to the operation part **21**. The plurality of types of work motions are operations for make the work machine **10** perform the plurality of types of motions, respectively. The operation part **21** may be provided in the cab **13**_a_ as shown in FIG. **1**. The operation part **21**, alternatively, may be provided outside the work machine **10** to allow remote control to be performed.

[0031] The operation part **21** includes a plurality of operation devices to which the plurality of types of work motions are applied, respectively. Each of the operation devices includes a work operation member and a manipulated variable generation part. To the work operation member is applied a corresponding work operation among the plurality of types of work motions. The work operation member may be, for example, either of an operation lever, an operation pedal, a touch panel and a key. The manipulated variable generation part generates the manipulated variable MV corresponding to the direction and magnitude of the work operation applied to the work operation member, namely, a drive command, and inputs the generated manipulated variable to the drive control part **19**. The manipulated variable generation part of each of the operation devices according to the present embodiment is composed of a pilot valve interposed between a non-illustrated pilot hydraulic pressure source (for example, a pilot pump) and a control valve **19**_c_ that corresponds to the operation device among the plurality of control valves **19**_c_, configured to be opened by the magnitude of the work operation so as to input a pilot pressure, which corresponds to the direction and magnitude of the work operation, to the control valve **19**_c_ as the manipulated

variable MV, namely, the drive command.
[0032] The manipulated variable MV is not limited to the pilot pressure (hydraulic pressure). For example, in the case where the plurality of actuators **17** include an electric actuator, the manipulated variable MV may be an electric signal (for example, a current value) to be input to the electric actuator. The manipulated variable MV is generated for each of the types of motions of the attachment **15**. In the present embodiment, the plurality of operation devices included in the operation part **21** correspond to the right turning motion, the left turning motion, the boom rising motion, the boom falling motion, the arm crowd motion, and the arm damp motion, the first tip attachment motion and the second tip attachment motion, respectively, and the operation devices generate respective pilot pressures corresponding to the types of motions as the manipulated variables MV, namely, the drive commands, and input them to the control valves **19***c*.
[0033] The manipulated variable MV has an effective range from the minimum manipulated variable MVmin to the maximum manipulated variable MVmax shown in FIG. **4**. With just the input of the manipulated variable MV that is less than the minimum manipulated variable MVmin to the control valve **19***c*, the actuator **17** corresponding to the control valve **19***c* is not activated; therefore, the motion corresponding to the actuator **17** (for example, boom rising motion) among the plurality of types of motions of the attachment **15** is not performed. The maximum manipulated variable MVmax is the maximum value of the manipulated variable MV that is input from the operation part **21** to the drive control part **19**. For example, in the case where the manipulated variable MV is a pilot pressure, the maximum manipulated variable MVmax is the maximum pilot pressure that can be input to the control valve **19***c* (for example, 3 MPa). By the input of the maximum manipulated variable MVmax, both the opening degree of the control valve **19***c* and the flow rate of the hydraulic fluid supplied from the control valve **19***c* to the actuator **17** is maximized, causing the actuator **17** to actuate the movable part that is connected to the actuator **17** at the maximum speed.
[0034] The automatic operation system is a system that generates a manipulated variable MV separately from the operation part **21** and inputs it to the driving device to thereby execute an automatic operation of the work machine **10**. Specifically, the automatic operation system includes a manipulated-variable detection device **23**, a posture detection device **25**, a controller **30**, which are shown in FIG. **2**, and a non-illustrated solenoid valve.
[0035] The manipulated-variable detection device **23** detects the manipulated variable MV which is input from the operation part **21** to the driving device (the drive control part **19** in the present embodiment). The manipulated-variable detection device **23** according to the present embodiment includes a plurality of manipulated-variable sensors that detect respective manipulated variables MV that are input from the plurality of operation devices to the plurality of control valves **19***c*, namely, respective pilot pressures, and each of the manipulated-variable sensors is a pressure sensor. In the case where the manipulated variable MV is an electrical signal, the manipulated-variable detection device **23** may either include a sensor that detects an electrical signal, such as a current sensor, or be included in the controller **30**.
[0036] The plurality of manipulated-variable sensors included in the manipulated-variable detection device **23** detect a plurality of manipulated variables MV corresponding to the types of motions of the attachment **15**, respectively. Specifically, the plurality of manipulated-variable sensors include a right turning manipulated-variable sensor **23***a***1**, a left turning manipulated-variable sensor **23***a***2**, a boom rising manipulated-variable sensor **23***b***1**, a boom falling manipulated-variable sensor **23***b***2**, an arm crowd manipulated-variable sensor **23***c***1**, an arm dump manipulated-variable sensor **23***c***2**, a tip attachment first manipulated-variable sensor **23***d***1** and a tip attachment second manipulated-variable sensor **23***d***2**, which sensors are shown in FIG. **2**.
[0037] Each of the manipulated-variable detection device **23**, the posture detection device **25** and the controller **30** may be either installed on the work machine **10** or placed outside the work machine **10**.

[0038] The posture detection device **25** detects a physical quantity related to the posture of the attachment **15**, serving as a speed information acquisition part that acquires speed information on a motion speed, which is the speed of the motion of the attachment **15**. The posture detection device **25** may detect either a physical quantity directly related to the posture of the attachment **15**, such as an angle or a position of a specific part of the attachment **15**, or a velocity or angular velocity of the specific part of the attachment **15**. In other words, the posture detection device **25** may be configured either to directly detect the speed of the motion of the attachment **15** or to detect information for indirectly acquiring the speed of the attachment **15**, for example, at least one of the posture and the acceleration (or angular acceleration).
[0039] The posture detection device **25** according to the present embodiment includes a plurality of sensors corresponding to respective motions of the attachment **15**, namely, a turning sensor **25***a*, a boom sensor **25***b*, an arm sensor **25***c* and a tip attachment sensor **25***d*, which are shown in FIG. **4**.
[0040] The turning sensor **25***a* detects a physical quantity related to the posture of the upper turning body **13** with respect to the lower traveling body **11** shown in FIG. **1**, namely, the turning posture that is the posture with respect to the turning direction. The turning sensor **25***a* is, for example, an angle sensor that detects the turning angle of the upper turning body **13** with respect to the lower traveling body **11**, the angle sensor being attachable to, for example, a turning shaft or a turning support part.
[0041] The boom sensor **25***b* detects a physical quantity related to the posture of the boom **15***b*. The boom sensor **25***b* is, for example, an angle sensor (for example, a rotary encoder) that detects the rotation angle (rising angle) of the boom **15***b* with respect to the upper turning body **13**, the angle sensor being attachable to the rotation support shaft of the boom **15***b*, namely, a boom foot pin, or the part that supports the boom **15***b*.
[0042] The arm sensor **25***c* is a sensor that detects a physical quantity related to the posture of the arm **15***c*, for example, an angle sensor that detects the rotation angle of the arm **15***c* with respect to the boom **15***b*. Similarly, the tip attachment sensor **25***d* is a sensor that detects a physical quantity related to the posture of the tip attachment **15***d*, for example, an angle sensor that detects the rotation angle of the tip attachment **15***d* with respect to the arm **15***c*.
[0043] The boom sensor **25***b*, the arm sensor **25***c* and the bucket sensor **25***d*, alternatively, may include tilt sensors (for example, gyro sensors, acceleration sensors, inertial measurement devices) which detect respective angles of the boom **15***b*, the arm **15***c* and the tip attachment **15***d* to the horizontal surface, namely, respective inclination angles thereof.
[0044] Alternatively, the boom sensor **25***b*, the arm sensor **25***c* and the tip attachment sensor **25***d* may be respective stroke sensors that detect the stroke of the boom cylinder **17***b*, the stroke of the arm cylinder **17***c*, and the stroke of the tip attachment cylinder **17***d*.
[0045] Alternatively, the turning sensor **25***a*, the boom sensor **25***b*, the arm sensor **25***c* and the tip attachment sensor **25***d* may detect physical quantities (including motion speeds) related to respective postures of the upper turning body **13**, the boom **15***b*, the arm **15***c* and the tip attachment **15***d* based on at least one of a two-dimensional image or a distance image.
[0046] The controller **30** is a device that performs arithmetic control operations for the automatic operation of the work machine **10** based on information acquired by the manipulated-variable detection device **23** and the posture detection device **25**, being composed of, for example, a computer including an interface that performs inputs and outputs signals, an calculation unit that performs calculation proceedings, and a storage unit that stores information. The functions of the controller **30** are provided, for example, through the execution of a program stored in the storage unit by the calculation unit. Specifically, the controller **30** shown in FIG. **2** includes a map generation part **41**, a map complementation part **43**, a map storage part **45**, a work plan setting part **51**, a target speed generation part **53** and a manipulated-variable calculation part **55**, which constitutes a manipulated-variable input part in association with the non-illustrated electromagnetic valve.

[0047] The map generation part **41** generates, for example, a map M shown in FIG. **4** based on the manipulated variable MV detected by the manipulated-variable detection device **23**, that is, the manual manipulated variable MVm that is input from the operation part **21** to the drive control part **19** through a manual operation by an operator, and the speed information acquired by the posture detection device **25**. The map M defines the relationship between a motion speed V provided by the speed information, that is, the speed of the motion of the attachment **15** (in the present embodiment, each of the types of motions), and the manipulated variable MV detected by the manipulated-variable detection device **23**. The map complementation part **43** performs complementation of the map M when the complementation is necessary. The case where the complementation is necessary and the detail of the complementation are described below. The map storage part **45** stores the map M. The map M stored in the map storage part **45** is the map generated by the map generation part **41** when no complementation is performed by the map complementation part **43**, or the complemented map when the complementation is performed by the map complementation part **43**.
[0048] The work plan setting part **51** sets a work plan for the work machine **10**. The work plan is information that serves as a target of the work motion of the work machine **10**. The work plan, in the present embodiment, includes information about a target trajectory T of the control target part **15***e* (the tip of the bucket in the example shown in FIG. **3**). The information about the target trajectory T includes respective positions (coordinates) of a plurality of target points of the control target part **15***e* included in the target trajectory T, and information about the order of the plurality of target points. The information about the target trajectory T may include, as information on the respective positions of the plurality of target points, at least one of information on the turning angle of the upper turning body **13**, information on the distance from the turning center of the upper turning body **13** with respect to the lower traveling body **11** to the control target part **15***e*, namely, a work radius, and information about the height of the control target part **15***e*. The information about the target trajectory T may include a movement time of the control target part **15***e* between adjacent target points among the plurality of target points or a parameter corresponding thereto.
[0049] The work plan that is set by the work plan setting part **51** according to the present embodiment includes a plurality of work phases F. Each of the work phases F includes information about the target trajectory T. The plurality of work phases F, in the work plan shown in FIG. **3**, include a series of phases, namely, a capture phase F**1**, a lifting and turning phase F**2**, a release phase F**3** and a return turning phase F**4**, the series of phases F**1** to F**4** constituting a single cycle.
[0050] The capture phase F**1** is a phase corresponding to a motion in which the tip attachment **15** captures a work object. The work object is not limited but allowed to be, for example, any of soil, wood, metal, and waste. The motion corresponding to the capture phase F**1** is, for example, the motion of excavating earth and sand of soil.
[0051] The lifting and turning phase F**2** corresponds to a lifting and turning motion in which the control target part **15***e* moves from a capture position at which the work object is to be captured to a release position at which the work object is to be released with the tip attachment **15***d* capturing the work object. The lifting and turning motion is a composite motion including at least the boom rising or falling motion and the turning motion, which motions are simultaneously performed.
[0052] The release phase F**3** corresponds to a release motion in which the tip attachment **15***d* releases the work object at the release position. The release motion is, for example, a motion for discharging soil to a vessel of a transport vehicle D shown in FIG. **3** or the like, including a rotational motion of the tip attachment **15***d*.
[0053] The return turning phase F**4** corresponds to a return turning motion in which the control target part **15***e* moves from the release position to a position where the tip attachment **15***d* captures a work object next time. The return turning motion is a composite motion including at least the boom rising or falling motion and the turning motion, which motions are simultaneously performed.

[0054] The work plan that is set by the work plan setting part **51** according to the present embodiment includes a plurality of cycles (e.g., ten times). The work plan setting part **51** may set, for example, different target trajectories T for respective cycles. The work plan setting part **51** may set, for example, the work plan so as to render respective target capture positions of the work objects in the plurality of cycles different from each other. The work plan setting part **51** may set, for example, the work plan so as to render respective target release positions of the work objects in the plurality of cycles different from each other. The work plan setting part **51** may set, for example, the work plan so as to terminate the series of cycles when a predetermined termination condition is satisfied. The termination condition is, for example, that the amount of the work object being laid in a place where the work object is to be collected (e.g., sediment pit S, etc.) is equal to or less than a predetermined value or that the number of cycles that has been performed is equal to a predetermined number of times. The work plan setting part **51** may set the work plan so as to start the next cycle when a predetermined restart condition is satisfied after one cycle is terminated. The restart condition is, for example, that a work object of a predetermined amount or more is replenished to a place where the work object is to be collected (such as a sediment pit S).
[0055] The work plan setting part **51** may set the work plan based on either the teaching executed by the operator or a method other than the teaching (e.g., numerical input by an operator, etc.). The teaching includes, for example, manually moving the control target part **15***c* along a trajectory corresponding to the desired target trajectory T by (i) application of a work operation to the operation part **21** by an operator getting on the work machine **10** or (ii) application of a work operation to the operation part **21** provided outside the work machine **10** by an operator. The work plan setting part **51** sets the trajectory along which the control target part **15***e* thus has been manually moved, as the target trajectory T.
[0056] The target speed generation part **53** generates a target speed during the performance of the automatic operation of the work machine **10**, i.e., a target value of the motion speed of the attachment **15**, for example, by calculation. The target speed generation part **53** according to the present embodiment generates a plurality of target speeds corresponding to the plurality of types of motions of the attachment **15**, respectively. Specifically, the target speed generation part **53** generates the plurality of target speeds so as to allow the work machine **10** to be automatically operated in accordance with the work plan set by the work plan setting part **51**, that is, so as to make the attachment **15** perform a motion corresponding to the work plan. The target speed generation part **53** generates the target speed so as to cause the control target part **15***c* to move along the target trajectory T.
[0057] The manipulated-variable calculation part **55** calculates the manipulated variable MV for making the attachment **15** perform each of the types of motions at the target speed generated by the target speed generation part **53**, namely, an automatic-operation manipulated variable MVa. Specifically, based on the target speed generated by the target speed generation part **53** and the map M complemented by the map complementation part **43** (or the map M generated by the map generation part **41** when no complementation is performed), the manipulated-variable calculation part **55** calculates the manipulated variable MV for making the attachment **15** perform the work motion at the target speed (automatic-operation manipulated variable MVa). The manipulated-variable calculation part **55** further generates a manipulated-variable command signal, which is an electric signal necessary for inputting the manipulated variable MV to the drive control part **19**, and inputs the manipulated-variable command signal to each of the solenoid valves.
[0058] The plurality of solenoid valves are interposed between the non-illustrated pilot hydraulic source and the plurality of control valves **19***c*, respectively, constituting a manipulated-variable input part in association with the manipulated-variable calculation part **55**. Each of the solenoid valves allows the manipulated-variable command signal to be input from the manipulated-variable calculation part **55** to the solenoid valve, and performs valve opening to allow the pilot pressure corresponding to the input manipulated-variable command signal, namely, the automatic-operation

manipulated variable MV to be input to the control valve **19***c*. The solenoid valve, which only has to be configured to change the secondary pressure of the solenoid valve, that is, the pilot pressure to be input to the control valve **19***c*, in response to the input electrical signal, may be either an electromagnetic proportional pressure regulation valve or an electromagnetic proportional reverse proportional valve.

[0059] Next will be described actions for automatic operation executed by the automatic operation system with reference to the flowcharts of FIGS. **5** and **6**. The actions for the automatic operation include the actions shown in FIG. **5**, i.e., (A) actions for the generation and complementation of the map M, and the actions shown in FIG. **6**, i.c., (B) actions for actually performing the automatic operation of the work machine **10**.

(A) Actions for Generation and Complementation of Map M

[0060] To generate the map M, a manual operation is performed by an operator (step S**11** in FIG. **5**). Specifically, a work operation is applied by an operator to each of the necessary operation devices included in the operation part **21**. The work operation to be applied to the operation part **21** may be either an operation performed for purpose of nothing but generating the map M or a teaching operation for setting the work plan. The operation part **21**, when the work operation is applied thereto, inputs a manipulated variable MV (pilot pressure in the present embodiment) corresponding to the work operation to the drive device (in the present embodiment, each of the control valves **19***c* of the drive control part **19**). The driving device, when the manipulated variable MV is input thereto, actuates the attachment **15** so as to make the attachment **15** perform the motion corresponding to the manipulated variable MV. Specifically, in the present embodiment, the pilot pressure as the manipulated variable MV is input to each of the control valves **19***c* of the drive control part **19** to make the control valve **19***c* perform valve opening by an opening degree corresponding to the pilot pressure, and the control valve **19***c* allows hydraulic fluid to be supplied to the actuator **17** that is connected to the control valve **19***c* among the plurality of actuators **17** at a flow rate corresponding to the pilot pressure.

[0061] On the other hand, the manipulated-variable detection device **23** detects the manipulated variable MV (the pilot pressure in the present embodiment) to be input from the operation part **21** to the drive control part **19**. Besides, the posture detection device **25** detects the motion speed V, which is a physical quantity related to the posture of the attachment **15** and which is the speed of the motion of each of the attachments **15**, for example, the operating speed of each of the actuators **17**.

[0062] The map generation part **41** of the controller **30** generates a map M indicating the relationship between the manipulated variable MV detected by the manipulated-variable detection device **23** in the manual operation, namely, the manual manipulated variable MVm, and the motion speed V acquired from the information detected by the posture detection device **25** when the manipulated variable MV is detected.

[0063] The map generation part **41** preferably generates a plurality of different maps M that correspond to a plurality of types of motions of the attachment **15** (for example, boom rising motion, boom falling motion) shown in FIG. **3**, respectively. In short, the map generation part **41** is preferably configured to generate the map M for each of the types of motions.

[0064] Preferably, the map generation part **41** generates different maps M corresponding to the plurality of work situations of the work machine **10**, respectively. In short, the map generation part **41** is preferably configured to generate the map M for each of the work situations. Examples of the working situation of the work machine **10** include the work phase F, the cycle, and other load conditions (the condition of the load acting on the attachment **15**).

[0065] Preferably, the map generation part **41** generates different maps M corresponding to the plurality of work phases F, respectively. In short, the map generation part **41** is preferably configured to generate the map M for each of the work phases F. The reason therefor is, for example, as follows. [0066] [1 Load Condition] Focusing on, for example, the boom **15***b* of the

attachment **15**, the condition of the load acting on the boom **15***b* is varied depending on the work phase F. This causes a case where the relationship between the manipulated variable MV and the motion speed V is varied depending on the work phase F even with the same work motion (e.g., boom rising motion) of the boom **15***b*. The same applies to the other work motions than the boom rising motion. It is preferable, therefore, that the map generation part **41** generates a plurality of different maps M corresponding to the plurality of work phases F, respectively. [0067] [2 Composite Motion] Different composite motions are performed depending on the work phases F. The composite motion is the simultaneous performance of a plurality of motions (e.g., the boom rising motion and the arm crowd motion) selected from the plurality of types of motions of the attachment **15**. In the composite motion, the hydraulic fluid discharged from the hydraulic pump **19***a* is distributed to a plurality of actuators (hydraulic actuators in the present embodiment) **17** corresponding to the plurality of motions, respectively. This causes a case where the motion speed V corresponding to the same motion (e.g., boom rising motion) and the same manipulated variable MV is varied depending on the work phase F. The same is the case other than the boom rising motion. Besides, also in the case where the plurality of actuators **17** are a plurality of electric actuators, limited power is distributed to the plurality of electric actuators. It is preferable, therefore, that the map generation part **41** generates a plurality of different maps M corresponding to the plurality of work phases F, respectively.
[0068] Table 1 below shows a specific example of the plurality of maps M generated by the map generation part **41** and corresponding to the plurality of types of motions and the plurality of phases F, respectively.
TABLE-US-00001 TABLE 1 TYPE OF MOTION BOOM BOOM ARM ARM TIP ATT TIP ATT RIGHT LEFT WORK RISING FALLING CROWD DUMP FIRST SECOND TURNING TURNING PHASE F MOTION MOTION MOTION MOTION MOTION MOTION MOTION MOTION CAPTURE BOOM BOOM ARM ARM TIP ATT TIP ATT RIGHT LEFT PHASE F1 RISING FALLING CROWD DUMP FIRST SECOND TURNING TURNING MAP 1 MAP 1 MAP 1 MAP 1 MAP 1 MAP 1 MAP 1 MAP 1 LIFTING BOOM BOOM ARM ARM TIP ATT TIP ATT RIGHT LEFT TURNING RISING FALLING CROWD DUMP FIRST SECOND TURNING TURNING PHASE F2 MAP 2 MAP 2 MAP 2 MAP 2 MAP 2 MAP 2 MAP 2 MAP 2 RELEASE BOOM BOOM ARM ARM TIP ATT TIP ATT RIGHT LEFT PHASE F3 RISING FALLING CROWD DUMP FIRST SECOND TURNING TURNING MAP 3 MAP 3 MAP 3 MAP 3 MAP 3 MAP 3 MAP 3 MAP 3 RETURN BOOM BOOM ARM ARM TIP ATT TIP ATT RIGHT LEFT TURNING RISING FALLING CROWD DUMP FIRST SECOND TURNING TURNING PHASE F4 MAP 4 MAP 4 MAP 4 MAP 4 MAP 4 MAP 4 MAP 4 MAP 4
[0069] Preferably, the map generation part **41** generates a plurality of different maps M corresponding to a plurality of cycles, respectively, the plurality of cycles composed of the series of work phases F, respectively. In summary, the map generation part **41** is preferably configured to generate the map M for each of the cycles. For example, there can be assumed a case where respective target trajectories T set in the plurality of cycles are different from each other, whereby respective conditions of the loads acting on the attachment **15** in the plurality of cycles are different from each other. This generates a possibility that the relationship between the manipulated variable MV and the motion speed V with the same operation (e.g., boom rising motion) and the same work phase F is varied depending on the cycle. This is the same as to a work operation other than the boom rising motion. It is, therefore, preferable that the map generation part **41** generates a plurality of different maps M corresponding to the cycles, respectively, the cycles composed of the series of work phases F, respectively.
[0070] The plurality of conditions of the load acting on the attachment **15** are not limited to those due to the work phase F or the cycle. The map generation part **41** may generate, for example, a plurality of different maps M depending on the condition (e.g., mass, size) of the object which is captured by the attachment **15**.

[0071] Alternatively, in the case of presence of a plurality of situations that are different from each other in the relationship between the manipulated variable MV and the motion speed V due to a cause other than the load acting on the attachment **15**, the map generation part **41** may generate a plurality of different maps M corresponding to the situations, respectively. In summary, the map generation part **41** is preferably configured to generate the map M for each of the situations.
[0072] When the maximum value of the manipulated variable MV included in the thus generated map M is smaller than a preset maximum manipulated variable MVmax (YES in step S**13**), the map complementation part **43** of the controller **30** complements the map M so as to render the maximum value of the manipulated variable MV of the map M equal to the maximum manipulated variable MVmax (step S**14**). The details are as follows.
[0073] Although the map generation part **41** generates the map M for defining the relationship between the manipulated variable MV and the motion speed V on the basis of the manipulated variable MV that is input to the drive control part **19** when a work operation is applied to the operation part **21** by the manual operation and the motion speed V (step S**11**), there can be a case where a work operation having a size corresponding to the maximum manipulated variable MVmax is not applied to the operation part **21** in the manual operation. For example, as shown in FIG. **4**, there can be a case where the maximum acquisition manipulated variable MV**1**, which is the maximum value of the manipulated variable (manual manipulated variable) MVm acquired by the manual operation, is less than the maximum manipulated variable MVmax. In this case, in the range where the manipulated variable MV is larger than the maximum acquisition manipulated variable MV**1**, that is, in the range where the motion speed V is larger than the maximum acquisition speed V**1** which is the motion speed corresponding to the maximum acquisition manipulated variable MV**1**, the manipulated-variable detection device **23** and the posture detection device **25** cannot acquire the manipulated variable MV and the motion speed V. Thus is generated a non-acquirable range where neither of the manipulated variable MV**1** and the motion speed V for generating the map M can be acquired by the manual operation, on the side where the manipulated variable MV**1** and the motion speed are larger than that in the ready-generated map portion M**1** which can be generated by the manual operation (right side and upper side in FIG. **4**).
[0074] The presence of the non-acquisition range causes, for example, the following problems. During automatic operation of the work machine **10** described below, the target speed generation part **53** of the controller **30** may generate a target speed greater than the maximum acquisition speed V**1** as a target speed Vt for the automatic operation. For example, during the performance of the automatic operation of the work machine **10** shown in FIG. **3**, an application of a load larger than the maximum value of the load applied to the attachment **15** when the manual operation is being performed (Step S**11**) may cause a target speed Vt greater than the maximum acquisition speed V**1** to be generated. The manipulated variable MV corresponding to the target speed Vt greater than the maximum acquisition speed V**1** (i.e., the manipulated variable MV greater than the maximum acquisition manipulated variable MV**1**), however, is not included in the ready-generated map portion M**1**. The ready-generated map portion M**1**, thus, cannot provide a target speed for making the attachment **15** perform the work motion at a speed greater than the maximum acquisition speed V**1**. Hence, the work machine **10**, in spite of its ability to actuate the attachment **15** at a motion speed V greater than the maximum acquisition speed V**1** (e.g., the maximum speed Vmax), cannot execute a control to make the attachment **15** perform a work motion at the motion speed V greater than the maximum acquisition speed V**1**. This hinders, for example, a delay of the actual position of the control target part **15***e* with respect to the position of the control target part **15***e* specified by the target trajectory T shown in FIG. **3** (that is, the target position) from being recovered.
[0075] Such a problem due to the presence of the non-acquisition range could be solved by an application of a work operation with a magnitude corresponding to the maximum manipulated variable MVmax to the operation part **21** by an operator in the manual operation (step S**11**);

however, this involves another problem as follows. For example, in the case of the map M generated based on the result of the teaching for the purpose of setting a work plan, etc., an operator has to apply a special operation for generating a map M in which the maximum acquisition manipulated variable MV**1** reaches the maximum manipulated variable Pmax, that is, a work operation greater than the maximum value of the work operation required for the teaching, to the operation part **21**, separately from the teaching. This increases the workload of the operator. Besides, the operation applied for generating such a map M that the maximum acquisition manipulated variable MV**1** reaches the maximum manipulated variable MVmax, that is, a work operation with the magnitude corresponding to the maximum manipulated variable MVmax, will cause a high-speed motion of the attachment **15** at the maximum speed Vmax. Such performance of the work motion by the attachment **15** at a speed more than the necessary motion speed during the manual operation requires an operator to pay attention to prevent the attachment **15** from coming into contact with surrounding objects, thus increasing the workload of the operator. Furthermore, it will force unaccustomed work operations upon operators who does not tend to perform a great work operation corresponding to the maximum manipulated variable MVmax (i.e., operators who tend to do work at relatively low speeds).

[0076] To solve the aforementioned problems, the map complementation part **43** complements the entire map M by compensating an additional map portion M**2** for the non-acquisition range in addition to the ready-generated map portion M**1**. Specifically, when the maximum acquisition manipulated variable MV**1**, which is the maximum value of the manipulated variable MV in the ready-generated map portion M**1**, does not reach the preset maximum manipulated variable MVmax (YES in step S**13**), the map complementation part **43** generates the additional map portion M**2** to complement the map M (Step S**14**). Specifically, the map complementation part **43** complements the map M so as to render the maximum value of the manipulated variable MV included in the map M equal to the maximum manipulated variable MVmax. On the other hand, when the maximum acquisition manipulated variable MV**1** reaches the maximum manipulated variable MVmax (NO in step S**13**), the map complementation part **43** performs no complementation of the map M, thus maintaining the map M generated by the map generation part **41** as it is.

[0077] For the case where a plurality of maps M are generated by the map generation part **41**, it is preferable that the map complementation part **43** complements each of the maps M. For example, in the case where the map generation part **41** has generated a plurality of different maps M corresponding to the plurality of types of motions of the attachment **15**, respectively, it is preferable that the map complementation part **43** complements each of the maps M corresponding to the plurality of types of motions, respectively. In the case where the map generation part **41** has generated a plurality of maps M corresponding to the work phases F, respectively, it is preferable that the map complementation part **43** complements each of the maps M corresponding to the work phases F, respectively. In the case where the map generation part **41** has generated a plurality of maps M corresponding to a plurality of cycles, respectively, the cycles composed of a series of the work phases F, respectively, it is preferable that the map complementation part **43** complements each of the maps M corresponding to the cycles, respectively.

[0078] The specific method of complementation by the map complementation part **43**, that is, the generation of the additional map portion M**2** in the present embodiment, is not limited. The additional map portion M**2** may be either (1) generated based on information on the maximum speed Vmax that is set in advance (e.g., stored in the controller **30**) or (2) estimated from the ready-generated map portion M**1**. The details are as follows.

(1) Generation of Additional Map Portion M**2** Based on Maximum Speed Vmax

[0079] The additional map portion M**2** can be generated based on information on the motion speed V corresponding to the maximum manipulated variable MVmax, namely, the maximum speed Vmax. The information is information set in advance of the complementation of the map M, for example, information prestored in the controller **30**.

[0080] The information of the maximum speed Vmax, for example, may be included in a base map BM as shown in FIG. **4**. The base map BM is prepared in advance, as a base of the map M, for example, prestored in the controller **30**. The base map BM defines the relationship between the manipulated variable MV and the motion speed V over the full range from the minimum manipulated variable MVmin to the maximum manipulated variable MVmax. The base map BM illustrated in FIG. **4** defines the relationship given by a straight line with a constant inclination. The base map BM, alternatively, may be provided in a curve.

[0081] The base map BM may be set cither prior to the shipping (e.g., during manufacturing) of the work machine **10** or by an operator or the like upon the start of work perform by the work machine **10** at a new work site. Alternatively, may be performed teaching for generating the base map BM prior to teaching for generating the map M.

[0082] Similarly to the map M, a plurality of base maps BM may be set correspondingly to various states of the work machine **10** (see FIG. **1**). For example, may be set either a plurality of base maps BM corresponding to the plurality of types of motions of the attachment **15** or a plurality of base maps BM corresponding to a plurality of conditions of a load acting on the attachment **15**.

[0083] In the case of the performance of teaching for generating the plurality of maps M corresponding to a plurality of states of the work machine **10**, a plurality of base maps BM corresponding to the plurality of states of the work machine **10** are used for the complementation of the maps M. For example, it is preferable that the condition of a load acting on the attachment **15** is detected when the teaching for generating each of the maps M is performed and the map complementation part **43** selects the base map BM corresponding to the detected load condition (e.g., equivalent to or close to the load condition) from among the plurality of base maps BM to complement the map M based on the selected base map BM.

[0084] The map complementation part **43** generates the additional map portion M**2** for the range where the manipulated variable MV is larger than the maximum acquisition manipulated variable MV**1**, without changing the ready-generated map portion M**1** (e.g., so as to directly reflect the teaching result onto the map M). Specifically, the map complementation part **43** performs the generation of the additional map portion M**2**, i.e., the complementation of the map M, based on the relationship between the maximum manipulated variable MVmax specified at the terminal end of the base map BM and the maximum speed Vmax. For example, the map complementation part **43** may either set, as shown in FIG. **4**, the maximum speed Vmax specified in the base map BM directly as the motion speed (maximum speed Vmax) corresponding to the maximum manipulated variable MVmax of the complemented map M or complement the map M by extending the map M from the ready-generated map portion M**1** to the maximum manipulated variable MVmax based on the inclination of the base map BM, that is, the rate of increase in the manipulated variable MV to the increase in the motion speed V. The ready-generated map portion M**1** may be slightly modified along with the generation of the additional map portion M**2**.

[0085] The maximum speed Vmax corresponding to the maximum manipulated variable MVmax is not limited to one based on the base map BM. For example, may be prestored in the controller **30** (in advance of the complementation of the map M) just the value of the maximum speed Vmax corresponding to the maximum manipulated variable MVmax. Besides, a plurality of maximum speeds Vmax corresponding to the maximum manipulated variable MVmax may be set correspondingly to the plurality of states of the work machine **10**. For example, the map complementation part **43** may select the maximum speed Vmax corresponding to the state of the work machine **10**, which state is acquired when teaching for setting the map M is performed, from among a plurality of maximum speeds Vmax prepared correspondingly to the maximum manipulated variable MVmax to complement the map M based on the thus selected maximum speed Vmax.

(2) Estimation From Previously-Generated Map Portion M**1**

[0086] The map complementation part **43** may complement the map M by estimating the additional map portion M**2** from the ready-generated map portion M**1**. For example, the map complementation part **43** may generate the additional map portion M**2** by extending the ready-generated map portion M**1**. The extension can be made based on, for example, the inclination of the terminal part of the graph that indicates the relationship between the motion speed V and the manipulated variable MV in the ready-generated map portion M**1**, i.e., the rate of increase in the manipulated variable MV to the increase in the motion speed V at the terminal part. The terminal part is the end part on the side closer to the maximum manipulated variable MVmax i n the graph (right side in FIG. **4**). For example, the inclination of the terminal end may be either of (a) the inclination at the terminal end of the ready-generated map portion M**1**, that is, the point corresponding to the maximum acquisition speed V**1** (a portion corresponding to the maximum acquisition manipulated variable MV**1**), (b) the average value of the inclination in the range from the speed V smaller than the maximum acquisition speed V**1** by a predetermined value to the maximum acquisition speed V**1** in the ready-generated map portion M**1**, (c) the average value of the inclination in the range from the manipulated variable MV**1** smaller than the maximum acquisition manipulated variable MV**1** by a predetermined value to the maximum acquisition manipulated variable MV**1** in the ready-generated map portion M**1**. The additional map portion M**2** generated by the map complementation part **43** may be either a straight line with the "inclination" that is set based on the ready-generated map portion M**1** or a line (e.g., a straight line or a curve) calculated based on the "inclination". The additional map portion M**2**, alternatively, may be generated based on the average value of the inclination of the entire ready-generated map portion M**1**.

[0087] Specific method for complementing the map M by the map complementation part **43** is not limited to above-described ones. For example, the map complementation part **43** may complement the map M based on both the base map BM and the inclination of the graph of the ready-generated map portion M**1**.

(B) Operations for Automatic Operation of Work Machine **10**

[0088] Next will be described arithmetic control operations to be performed for the automatic operation of the work machine **10** with reference to the flowchart of FIG. **6**.

[0089] The target speed generation part **53** of the controller **30** generates a target speed Vt so as to make the work machine **10** perform the plurality of types of motions according to the work plan that is set by the work plan setting part **51** (Step S**21**). Specifically, the target speed generation part **53** generates a plurality of target speeds Vt corresponding to the plurality of types of motions (e.g., boom rising motion, boom falling motion) of the attachment **15**, respectively. The target speed generation part **53** inputs (instructs) the thus generated target speed to the manipulated-variable calculation part **55**.

[0090] The manipulated-variable calculation part **55** reads, from the map storage part **45**, the map M corresponding to the current work state of the work machine **10** among the plurality of maps M stored in the map storage part **45** (Step S**22**). For example, the manipulated-variable calculation part **55** reads a plurality of maps M corresponding to the types of motions of the attachment **15**, respectively. Other examples of the map M to be read by the manipulated-variable calculation part **55** include a map M corresponding to the current load condition of the attachment **15**, a map M corresponding to the current work phase F, and a map M corresponding to the current cycle.

[0091] Based on the map M read from the map storage part **45**, the manipulated-variable calculation part **55** calculates (determines) the manipulated variable MV corresponding to the target speed Vt generated by the target speed generation part **53**, namely, an automatic-operation manipulated variable MVa (Step S**23**). For example, according to the map M shown in FIG. **4**, when the target speed Vt generated by the target speed generation part **53** is equal to or less than the maximum acquisition speed V**1**, the manipulated-variable calculation part **55** calculates the manipulated variable MV corresponding to the target speed Vt based on the ready-generated map portion M**1**, whereas, when the target speed Vt is larger than the maximum acquisition speed V**1**, the manipulated-variable calculation part **55** calculates the manipulated variable MV corresponding to the target speed Vt based on the additional map portion M**2** added by the map complementation part **43**.

[0092] The manipulated-variable calculation part **55** generates a manipulated-variable command signal for providing the thus determined manipulated variable MV (pilot pressure in the present embodiment) and inputs it to the not-illustrated solenoid valve (Step S**24**). The solenoid valve is opened so as to allow the pilot pressure to be input to the drive control part **19** in response to the manipulated-variable command signal. The drive control part **19** changes the movement of the actuator **17** corresponding to the manipulated variable MV among the plurality of actuators **17** based on the input pilot pressure, i.e., the manipulated variable MV (automatic-operation manipulated variable MVa). Thus, the automatic operation of the work machine **10** based on the target speed Vt generated by the target speed generation part **53** is performed. In the case where the actuator **17** is an electric actuator, an electric signal (command signal) corresponding to the manipulated variable MV may be either directly input to the electric actuator from the manipulated-variable calculation part **55** or input to a circuit for controlling the action of the electric actuator.

[0093] The complementation of the map M by the map complementation part **43** enables the followability of the motion speed V to the target speed Vt in the automatic operation to be improved. For example, below will be described assuming the case where the control target part **15***c* has an actual motion speed V that is lower than the target speed Vt of the control target part **15***e* because of the large load acting on the attachment **15**, which deviates (delays) the actual control target part **15***e* from the target position of the control target part **15***e* at a certain point in time. In this case, the target speed generation part **53** generates a high target speed Vt so as to reduce the delay; however, if the target speed Vt is greater than the maximum acquisition speed V**1** shown in FIG. **4**, the manipulated variable MV corresponding to the target speed Vt cannot be calculated with only the ready-generated map portion M**1**. In summary, without complementation of the map M by the map complementation part **43**, the manipulated-variable calculation part **55** cannot calculate the manipulated variable MV corresponding to the target speed Vt that exceeds the maximum acquisition speed V**1**. In contrast, the complementation of the map M by the map complementation part **43**, i.e., the addition of the additional map portion M**2**, enables the manipulated-variable calculation part **55**, even when the target speed Vt is greater than the maximum acquisition speed (for example, the maximum value of the speed V when the work plan is taught) V**1**, to calculate the manipulated variable MV corresponding to the target speed Vt (>V**1**) based on the additional map portion M**2**, thereby allowing the delay of the speed V and the position of the control target part **15***e* to be quickly reduced.

[0094] The embodiments described above may be variously modified. For example, the connection of each component shown in FIG. **2** of the above embodiment may be changed. For example, the order of the steps of the flowcharts illustrated in FIGS. **5** and **6** may be changed and some of the steps may not be performed. For example, the number of components may be changed and some of the components may not be provided. For example, the fixation, connection, etc. of the components may be direct or indirect. For example, what has been described as a plurality of members or parts different from each other may be one member or part. For example, what has been described as one member or part may be divided into a plurality of members or parts different from each other. For example, each component may have only a portion of each feature (working function, arrangement, shape, actuation, etc.).

[0095] As has been described, there is provided a system for performing an automatic operation of a work machine, the system being capable of making the speed of the motion of a work device of the work machine quickly follow a target speed. The system is a system for performing an automatic operation of a work machine that includes a machine body, a work device, an operation part, and a driving device. The system includes a manipulated-variable detection device, a speed

information acquisition device, a map generation part, a map complementation part, a target speed generation part **53**, and a manipulated-variable input part. The work device is attached to the machine body capably of performing a work motion. The driving device allows a manipulated variable to be input to the driving device, and makes the work device perform the work motion in accordance with the manipulated variable. The operation part allows a work operation for operating the work device to be applied to the operation part, and inputs the manipulated variable corresponding to the work operation to the driving device. The manipulated-variable detection device detects the manipulated variable to be input from the operation part to the driving device. The speed information acquisition device acquires speed information on a motion speed that is a speed of the work motion of the work device. The map generation part generates a map based on the manipulated variable detected by the manipulated-variable detection device and the speed information acquired by the speed information acquisition device. The map defines a relationship between the manipulated variable and the motion speed of the work device. When a maximum value of the manipulated variable included in the map generated by the map generation part is smaller than a preset maximum manipulated variable, the map complementation part complements the map so as to render the maximum value of the manipulated variable of the map equal to the maximum manipulated variable. The target speed generation part generates a target speed that is a target value of the motion speed for an automatic operation of the work machine. The manipulated-variable input part generates the manipulated variable for making the work device perform the work motion at the target speed based on the target speed generated by the target speed generation part and the map complemented by the map complementation part, and inputs the manipulated variable to the driving device.
[0096] The map complementation part enables the manipulated-variable input part to generate the manipulated variable corresponding to the target speed based on the complemented map and input the manipulated variable to the driving device even when a target speed greater than a maximum value of the manipulated variable included in the map generated by the map generating part is generated by the target speed generating part. This makes it possible to perform a control for reducing a delay caused by the lower actual motion speed of the work device in the automatic operation than the target speed, thereby allowing the followability of the motion speed of the work device to the target speed to be improved.
[0097] Preferably, the map complementation part is configured to complement the map based on information that is preset for the motion speed corresponding to the maximum manipulated variable. This allows the map to be complemented by a simple operation.
[0098] Preferably, the map complementation part is configured to complement the map based on an inclination of a graph that indicates a relationship between the motion speed and the manipulated variable in the map generated by the map generating part. The map complementation part can complement the map without requiring any special information other than the map portion that has been already generated by the map generating part.
[0099] For the case where the work device is capable of performing a plurality of types of motions as the work motion, it is preferable that the map generation part is configured to generate the map for each of the types of motions and the map complementation part is configured to complement the map generated for each of the types of motions.
[0100] Such generation and complementation of the map corresponding to each of the types of motions of the work device enables the followability of the motion speed of the work device to the target speed to be enhanced.
[0101] The automatic operation system, for example, can be applied to a work machine in which the machine body includes a lower traveling body and an upper turning body mounted on the lower traveling body capably of turning and the work device includes a boom that is attached to the upper turning body capably of rising and falling, an arm that is connected to the boom capably of vertically rotational movement, and a tip attachment that is connected to the arm capably of

vertically rotational movement. In this case, the plurality of types of motions include a turning motion of the upper turning body with respect to the lower traveling body, a rising and falling motion of the boom with respect to the upper turning body, a rotational movement of the arm with respect to the boom, and a rotational movement of the tip attachment with respect to the arm.
[0102] Preferably, the map generation part is configured to generate the map for each of different work situations of the work machine, and the map complementation part is configured to complement the map generated for each of the work situations. This allows the followability of the motion speed of the work machine to the target speed to be improved in each of the work situations of the work machine.

Claims

1. An automatic operation system for performing an automatic operation of a work machine that includes a machine body, a work device attached to the machine body capably of performing a work motion, a driving device and an operation part, the driving device allowing a manipulated variable to be input to the driving device and configured to make the work device perform the work motion in accordance with the manipulated variable, the operation part allowing a work operation for operating the work device to be applied to the operation part and configured to input the manipulated variable corresponding to the work operation to the driving device, the automatic operation system comprising: a manipulated-variable detection device that detects the manipulated variable that is input from the operation part to the driving device; a speed information acquisition device that acquires speed information on a motion speed that is a speed of the work motion of the work device; a map generation part that generates a map that defines a relationship between the speed information acquired by the speed information acquisition device and the manipulated variable detected by the manipulated-variable detection device; a map complementation part that complements the map, when a maximum value of the manipulated variable included in the map generated by the map generation part is smaller than a preset maximum manipulated variable, so as to render the maximum value of the manipulated variable of the map equal to the maximum manipulated variable; a target speed generation part that generates a target speed that is a target value of the motion speed for the automatic operation of the work machine; and a manipulated-variable input part that generates the manipulated variable for making the work device perform the work motion at the target speed based on the target speed generated by the target speed generation part and the map complemented by the map complementation part and inputs the manipulated variable to the driving device.
2. The automatic operation system according to claim 1, wherein the map complementation part is configured to complement the map based on information that is preset for the motion speed corresponding to the maximum manipulated variable.
3. The automatic operation system according to claim 1, wherein the map complementation part is configured to complement the map based on an inclination of a graph that indicates a relationship between the motion speed and the manipulated variable in the map generated by the map generating part.
4. The automatic operation system according to claim 1, wherein: the work device is capable of performing a plurality of types of motions as the work motion; the map generation part is configured to generate the map for each of the types of motions; and the map complementation part is configured to complement the map generated for each of the types of motions.
5. The automatic operation system according to claim 4, wherein: the machine body includes a lower traveling body and an upper turning body mounted on the lower traveling body capably of turning; the work device includes a boom that is attached to the upper turning body capably of rising and falling, an arm that is connected to the boom capably of vertically rotational movement, and a tip attachment that is connected to the arm capably of vertically rotational movement; and the

plurality of types of motions include a turning motion of the upper turning body with respect to the lower traveling body, a rising and falling motion of the boom with respect to the upper turning body, a rotational movement of the arm with respect to the boom, and a rotational movement of the tip attachment with respect to the arm.

6. The automatic operation system according to claim 1, wherein the map generation part is configured to generate the map for each of different work situations of the work machine, and the map complementation part is configured to complement the map generated for each of the work situations.