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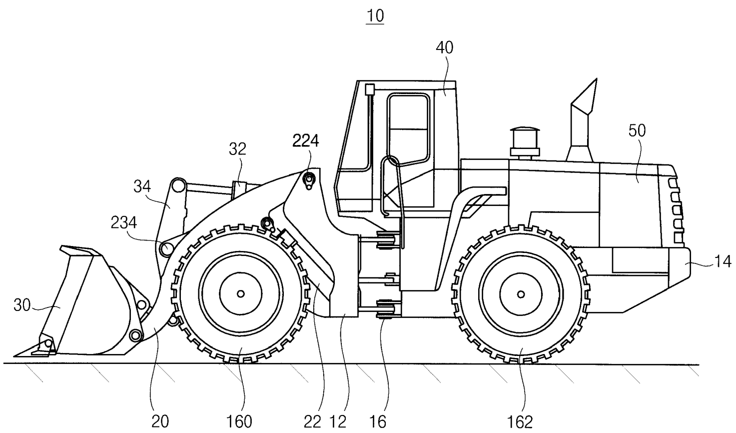
(54) METHOD AND APPARATUS FOR CONTROLLING A WHEEL LODER

(57) In a method of controlling a wheel loader, signals representing a state of work currently performed by the wheel loader, are received from sensors installed in the wheel loader. One or more signals are selected of the received signals, the one or more signals able to be used to determine whether or not to be within a respective one of a plurality of individual load areas, wherein the individual load areas are divided according to work load which consumes a power output of an engine during a series of work states performed by the wheel loader. Output values representing as to whether or not to be within the respective one of the plurality of individual load areas, are calculated by using the selected signal. The output values are analyzed to determine a current load state of the work currently performed by the wheel loader.

FIG. 1



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Description

BACKGROUND

1. Field

[0001] The invention relates to a method of controlling a wheel loader, an apparatus for controlling the wheel loader, and a system for controlling the wheel loader. More particularly, the invention relates to a method of determining a work state of a wheel loader to automatically control the wheel loader, and a control apparatus and a control system for performing the same.

2. Description of the Related Art

[0002] In general, an industrial vehicle such as a wheel loader is widely used to excavate sand, gravel, and the like and load it into a dump truck.

[0003] When the wheel loader performs a series of work states, work load, which consumes a power output of an engine of the wheel loader, may changes according to the work states. However, it is difficult and very burdensome to manually select an optimal power mode adapted for the changing work states. These work states may be detected and then the engine or a transmission of the wheel loader may be controlled automatically based on the detected results, thereby improving fuel efficiency and preventing deterioration of operating performance. Accordingly, a new technique capable of precisely detecting a current work state and a current work load state in real time and automatically control the wheel loader may be required.

SUMMARY

[0004] The invention sets-out to solve the above-mentioned problems of the art and provides a method of controlling a wheel loader, which reduces fuel consumption and improves operating performance.

[0005] The invention also seeks to provide a control apparatus for performing the above method.

[0006] The invention still also seeks to provide a control system for performing the above method.

[0007] According to embodiments of the invention, in a method of controlling a wheel loader, signals representing a state of work currently performed by the wheel loader, are received from sensors installed in the wheel loader. One or more signals are selected of the received signals, the one or more signals able to be used to determine whether or not to be within a respective one of a plurality of individual load areas, wherein the individual load areas are divided according to work load which consumes a power output of an engine during a series of work states performed by the wheel loader. Output values representing as to whether or not to be within the respective one of the plurality of individual load areas, are calculated by using the selected signal. The output values are analyzed to determine a current load state of the work currently performed by the wheel loader.

[0008] In example embodiments, calculating the output values may include using machine learning to calculate the output values. Machine leaning may include neural networks approach, statistical approach, structural approach, fuzzy logic approach, decision tree approach, template matching approach, etc.

[0009] In example embodiments, calculating the output values may include using a table stored in a memory by a wheel loader manufacturer to calculate the output values.

[0010] In example embodiments, calculating the output values may include performing prediction algorithms obtained through training on the selected signal to calculate the output values. The prediction algorithm may include connection weights between an input layer, a hidden layer and an output layer.

[0011] In example embodiments, calculating the output values may include calculating an output value representing as to whether or not to be within a light load area, calculating an output value representing as to whether or not to be within a medium load area, calculating an output value representing as to whether or not to be within a heavy load area and calculating an output value representing as to whether or not to be within an acceleration/inclined-ground load area.

[0012] In example embodiments, at least one of a boom cylinder pressure signal, an FNR signal, a main pressure signal of a hydraulic pump, a vehicle speed signal, a boom position signal and a torque converter speed ratio signal may be used to determine whether or not to be within the light load area and the heavy load area of the wheel loader, at least one of the main pressure signal of the hydraulic pump, the vehicle speed signal, a boom position signal and the torque converter speed ratio signal may be used to determine whether or not to be within the medium load area of the wheel loader.

[0013] In example embodiments, at least one of a torque converter speed ratio signal and an accelerator pedal position signal may be used to determine whether or not to be within the acceleration/inclined-ground load area of the wheel loader.

[0014] In example embodiments, a forward travelling work state, a reverse travelling work state and a reverse travelling and boom down work state in a V-shape driving of the wheel loader may be determined as a light load state, an excavation work state may be determined as a medium load state, and a forward travelling and boom raising work state may be determined as a heavy load state.

[0015] In example embodiments, the method may further include outputting a control signal for controlling an engine or a transmission of the wheel loader according to the current load state of the wheel loader.

[0016] According to embodiments of the invention, an apparatus for controlling a wheel loader, includes a signal receiver configured to receive signals representing a state of work currently performed by the wheel loader, from sensors installed in the wheel loader, a signal selector configured to provide a plurality of individual load areas according to work load which consumes a power output of an engine during a series of work states performed by the wheel loader and configured to select one or more signals of the received signals, the one or more signals able to be used to determine whether or not to be within a respective one of the plurality of individual load areas, an individual load area determiner configured to calculate output values representing as to whether or not to be within the respective one of the plurality of individual load areas, by using the selected signal, and a load state determiner configured to analyze the output values to determine a current load state of the work currently performed by the wheel loader.

[0017] In example embodiments, the individual load area determiner may include individual calculating circuits which calculate the output values using machine learning.

[0018] In example embodiments, machine leaning may include neural networks approach, statistical approach, structural approach, fuzzy logic approach, decision tree approach, template matching approach, etc.

[0019] In example embodiments, the individual load area determiner may calculate the output values using a table stored in a memory.

[0020] In example embodiments, the individual load area determiner may perform prediction algorithms obtained through training on the selected signal to calculate the output values. The prediction algorithm may include connection weights between an input layer, a hidden layer and an output layer.

[0021] In example embodiments, when the signal receiver receives an auto mode selection signal of an operator, a state of the work currently performed by the wheel loader may be determined to automatically control the wheel loader.

[0022] In example embodiments, the individual load area determiner may include a light load determining circuit which calculates an output value representing as to whether or not to be within a light load area, a medium load determining circuit which calculates an output value representing as to whether or not to be within a medium load area, a heavy load determining circuit which calculates an output value representing as to whether or not to be within a heavy load area, and an acceleration/inclined-ground determining circuit which calculates an output value representing as to whether or not to be within an acceleration/inclined-ground load area.

[0023] In example embodiments, the light load determining circuit and the heavy load determining circuit may use at least one of a boom cylinder pressure signal, an FNR signal, a main pressure signal of a hydraulic pump, a vehicle speed signal, a boom position signal and a torque converter speed ratio signal to determine whether or not to be within the light load area and the heavy load area of the wheel loader, the medium load determining circuit may use at least one of the main pressure signal of the hydraulic pump, the vehicle speed signal, a boom position signal and the torque converter speed ratio signal to determine whether or not to be within the medium load area of the wheel loader.

[0024] In example embodiments, the acceleration/inclined-ground load determining circuit may use at least one of a torque converter speed ratio signal and an accelerator pedal position signal to determine whether or not to be within the acceleration/inclined-ground load area of the wheel loader.

[0025] In example embodiments, the load state determiner may determine a forward travelling work state, a reverse travelling work state and a reverse travelling and boom down work state in a V-shape driving of the wheel loader as a light load state, may determine an excavation work state as a medium load state, and may determine a forward travelling and boom raising work state determined as a heavy load state.

[0026] In example embodiments, the apparatus may further include a control signal generator configured to output a control signal for controlling an engine or a transmission of the wheel loader according to the current load state of the wheel loader.

[0027] In example embodiments, the control signal generator may output a signal for controlling torque of an engine according to a predetermined auto engine torque map.

[0028] In example embodiments, the auto engine torque map may be set different from a manual engine torque map, the engine being controlled according to the manual engine torque map when an operator select an manual mode.

[0029] According to embodiments of the invention, a system for controlling a wheel loader, includes an engine, a work apparatus and a travel apparatus driven by the engine, sensors installed in the engine, the work apparatus and the travel apparatus to detect signals representing a state of work currently performed by the wheel loader, and a control apparatus configured to one or more signals of the received signals, the one or more signals able to be used to determine whether or not to be within a respective one of a plurality of individual load areas which are divided according to work load which consumes a power output of an engine during a series of work states performed by the wheel loader and configured to perform prediction algorithms obtained through training to determine whether or not to be within the respective one of the plurality of individual load areas and responsively determine a current load state of the work currently performed by the wheel loader.

[0030] In example embodiments, the control apparatus may select the one or more signals of the received signals, may calculate output values representing as to whether or not to be within the respective one of the plurality of individual load areas, by using the selected signal, and may analyze the output values to determine the current load state.

[0031] In example embodiments, the control apparatus may perform neural network algorithms on the selected signals to calculate the output values.

[0032] In example embodiments, the control apparatus may calculate an output value representing as to whether or not to be within a light load area, may calculate an output value representing as to whether or not to be within a medium load area, may calculate an output value representing as to whether or not to be within a heavy load area, and may calculate an output value representing as to whether or not to be within an acceleration/inclined-ground load area.

[0033] In example embodiments, the control apparatus may determine a forward travelling work state, a reverse travelling work state and a reverse travelling and boom down work state in a V-shape driving of the wheel loader as a light load state, may determine an excavation work state as a medium load state, and may determine a forward travelling and boom raising work state determined as a heavy load state.

[0034] In example embodiments, the control apparatus may output a control signal for controlling the engine or a transmission of the wheel loader according to the current load state of the wheel loader.

[0035] According to example embodiments, a control apparatus for a wheel loader may select signals capable of effectively representing an individual load state (light load area, medium load area, heavy load area, acceleration/inclined-ground load area) of signals received from sensors and determine a load state of a current work or a current work state by using prediction algorithms obtained through training such as neural network algorithms.

[0036] Thus, the time and burden spent on calculations in order to determine a load state of work currently performed by the wheel loader may be reduced and the accuracy of the determinations may be improved. Further, an engine and a transmission may be controlled based on the determined work load state to thereby improve operating performance and fuel efficiency.

[0037] At least some of the above and other features of the invention are set out in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0038]

Example embodiments will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings. FIGS. 1 to 11C represent non-limiting, example embodiments as described herein.

FIG. 1 is a side view illustrating a wheel loader in accordance with example embodiments.

FIG. 2 is a block diagram illustrating a system for controlling the wheel loader in FIG. 1.

FIG. 3 is a block diagram illustrating a control apparatus for a wheel loader in accordance with example embodiments.

FIG. 4 is a block diagram illustrating a signal selector, an individual load area determiner and a load state determiner of the control apparatus in FIG. 3.

FIG. 5 is a view illustrating a neural network circuit in the individual load area determiner in FIG. 4.

FIG. 6 is a view illustrating a signal transfer in each layer of the neural network in FIG. 5.

FIG. 7 is a flow chart illustrating a method of controlling a wheel loader in accordance with example embodiments.

FIG. 8 is a view illustrating V-shape driving of a wheel loader in accordance with example embodiments.

FIG. 9 is graphs illustrating output values representing whether or not to be within a respective one of individual load areas in each work state in the V-shape driving of FIG. 8.

FIG. 10 is a graph illustrating a final load state obtained from the output values of FIG. 9.

FIGS. 11A to 11C are graphs illustrating manual engine torque maps for three power modes in a manual mode and auto engine torque maps for three power modes in an auto mode.

DESCRIPTION OF EMBODIMENTS

[0039] Various example embodiments will be described more fully hereinafter with reference to the accompanying drawings, in which some example embodiments are shown. The present inventive concept may, however, be embodied in many different forms and should not be construed as limited to the example embodiments set forth herein. Rather, these example embodiments are provided so that this description will be thorough and complete, and will fully convey the scope of the present inventive concept to those skilled in the art. In the drawings, the sizes and relative sizes of layers and regions may be exaggerated for clarity.

[0040] It will be understood that when an element or layer is referred to as being "on," "connected to" or "coupled to" another element or layer, it can be directly on, connected or coupled to the other element or layer or intervening elements or layers may be present. In contrast, when an element is referred to as being "directly on," "directly connected to" or "directly coupled to" another element or layer, there are no intervening elements or layers present. Like numerals refer to like elements throughout. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0041] It will be understood that, although the terms first, second, third, fourth etc. may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms are only used to distinguish one element, component, region, layer or section from another region, layer or section. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the present inventive concept.

[0042] The terminology used herein is for the purpose of describing particular example embodiments only and is not intended to be limiting of the present inventive concept. As used herein, the singular forms "a," "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[0043] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this inventive concept belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0044] FIG. 1 is a side view illustrating a wheel loader in accordance with example embodiments. FIG. 2 is a block diagram illustrating a system for controlling the wheel loader in FIG. 1.

[0045] Referring to FIGS. 1 and 2, a wheel loader 10 may include a front body 12 and a rear body 14 connected to each other. The front body 12 may include a work apparatus and a front wheel 160. The rear body 14 may include a driver cabin 40, an engine bay 50 and a rear wheel 162.

[0046] The work apparatus may include a boom 20 and a bucket 30. The boom 20 may be freely pivotally attached to the front body 12, and the bucket 30 may be freely pivotally attached to an end portion of the boom 20. The boom 20 may be coupled to the front body 12 by a pair of boom cylinders 22, and the boom 20 may be pivoted upwardly and downwardly by expansion and contraction of the boom cylinders 22. A tilt arm 34 may be freely rotatably supported on the boom 20, almost at its central portion. One end portion of the tilt arm 34 may be coupled to the front body 12 by a pair of bucket cylinders 32 and another end portion of the tilt arm 34 may be coupled to the bucket 30 by a tilt rod, so that the bucket 30 may pivot (crowd and dump) as the bucket cylinder 32 expands and contracts.

[0047] The front body 12 and the rear body 14 may be rotatably connected to each other through a center pin 16 so that the front body 12 may swing side to side with respect to the rear body 14 by expansion and contraction of a steering cylinder (not illustrated).

[0048] A travel apparatus for propelling the wheel loader 10 may be mounted at the rear body 14. An engine 100 may be provided in the engine bay 50 to supply an output power to the travel apparatus. The travel apparatus may include a torque converter 120, a transmission 130, a propeller shaft 150, axles 152, 154, etc. The output power of the engine 100 may be transmitted to the front wheel 160 and the rear wheel 162 through the torque converter 120, the transmission 130, the propeller shaft 150 and the axles 152 and 154, and thus the wheel loader 10 may travels.

[0049] In particular, the output power of the engine 100 may be transmitted to the transmission 130 through the torque converter 120. An input shaft of the torque converter 120 may be connected to an output shaft of the engine 100, and an output shaft of the torque converter 120 may be connected to the transmission 130. The torque converter 120 may be a fluid clutch device including an impeller, a turbine and a stator. The transmission 130 may include hydraulic clutches that shift speed steps between first to fourth speeds, and rotation of the output shaft of the torque converter 120 may be shifted by the transmission 130. The shifted rotation may be transmitted to the front wheel 160 and the rear wheel 162 through the propeller shaft 150 and the axles 152 and 154 and thus the wheel loader may travel.

[0050] The torque converter 120 may have a function to increase an output torque with respect to an input torque, i.e., a function to make the torque ratio 1 or greater. The torque ratio may decrease with an increase in the torque converter speed ratio e (=Nt/Ni), which is a ratio of the number of rotations Nt of the output shaft of the torque converter 120 to the number of rotations Ni of the input shaft of the torque converter 120. For example, if travel load is increased while the vehicle is in motion in a state where the engine speed is constant, the number of rotations of the output shaft of the torque converter 120, i.e., the vehicle speed may be decreased. At this time, the torque ratio may be increased and thus the vehicle may be allowed to travel with a greater travel driving force (traction force).

[0051] The transmission 130 may include a forward hydraulic clutch for forward movement, a reverse hydraulic clutch for reverse movement, and first to fourth hydraulic clutches for the first to the fourth speeds. The hydraulic clutches may be each engaged or released by pressure oil (clutch pressure) supplied via a transmission control unit (TCU) 140. The hydraulic clutches may be engaged when the clutch pressure supplied to the hydraulic clutches is increased, while the hydraulic clutches may be released when the clutch pressure is decreased.

[0052] When travel load is decreased and the torque converter speed ratio e is increased to be equal to or greater than a predetermined value eu, a speed step may be shifted by one step. On the other hand, when travel load is increased and the torque converter speed ratio e is decreased to be equal to or less than a predetermined value ed, the speed step may be shifted by one step.

[0053] The transmission 130 may be operable in a manual transmission mode or in a plurality of auto transmission modes. The transmission mode may be determined by a changed by manipulation of a mode shift lever (not illustrated). For example, the transmission 130 may include manual transmission mode, 1-4 auto transmission mode and 1-3 auto transmission mode. When the manual transmission mode is selected, a speed step may be selected by a transmission shift lever. When the 1-4 auto transmission mode or the 1-3 auto transmission mode is selected, a speed step may be automatically changed between speed steps equal to or less than a speed step selected by the transmission shift lever.

[0054] A variable capacity hydraulic pump 200 for supplying a pressurized hydraulic fluid to the boom cylinder 22 and the bucket cylinder 32 may be mounted at the rear body 14. The variable capacity hydraulic pump 200 may be driven using a portion of the power outputted from the engine 100. For example, the output power of the engine 100 may drive the hydraulic pump 200 for the work apparatus and a hydraulic pump (not illustrated) for the steering cylinder via a power take-off (PTO) such as a gear train 110.

[0055] A pump control device (EPOS, Electronic Power Optimizing System) may be connected to the variable capacity hydraulic pump 200, and a discharge fluid from the variable capacity hydraulic pump 200 may be controlled by the pump control device. A main control valve (MCV) including a boom control valve 210 and a bucket control valve 212 may be installed on a hydraulic circuit of the hydraulic pump 200. The discharge fluid from the hydraulic pump 200 may be supplied to the boom cylinder 22 and the bucket cylinder 32 through the boom control valve 210 and the bucket control valve installed in a hydraulic line 202 respectively. The main control valve (MCV) may supply the discharge fluid from the hydraulic pump 200 to the boom cylinder 22 and the bucket cylinder 32 according to a pilot pressure in proportion to an operation rate of an operating lever.

[0056] A maneuvering device may be provided within the driver cabin 40. The maneuvering device may include an accelerator pedal 142, a brake pedal 144, an FNR travel lever, the operating levers for operating the cylinders such as the boom cylinder 22 and the bucket cylinder 32, etc.

[0057] As mentioned above, the wheel loader 10 may include a traveling operating system for driving the travel apparatus via the PTO and a hydraulic operating system for driving the work apparatus such as the boom 20 and the bucket 30 using the output power of the engine 100.

[0058] Further, a control apparatus 300 for the wheel loader 10 such as a portion of a vehicle control unit (VCU) or a separate control unit may be mounted in the rear body 14. The control apparatus 300 may include an arithmetic processing unit having a CPU which executes a program, a storage device such as a memory, other peripheral circuit, and the like.

[0059] The control apparatus 300 may receive signals from various sensors (detectors) which are installed in the wheel loader 10. For example, the control apparatus 300 may be connected to an engine speed sensor 102 for detecting a rotational speed of the engine, an accelerator pedal detection sensor 143 for detecting an operation amount of the accelerator pedal 142, a brake pedal detection sensor 145 for detecting an operation amount of the brake pedal 144, and an FNR travel lever position sensor 146 for detecting a manipulation position of the FNR travel lever, for example, the speed steps, forward (F), neutral (N) and reverse (R).

[0060] Additionally, the control apparatus 300 may connected to a rotational speed sensor 122a for detecting the number of rotations Ni of the input shaft of the torque converter 120, a rotational speed sensor 122b for detecting the number of rotations Nt of the output shaft of the torque converter 120, and a vehicle speed sensor 132 for detecting a rotational speed of an output shaft of the transmission 130, i.e., a vehicle speed v.

[0061] Further, the control apparatus 300 may be connected to a pressure sensor 204 installed in the hydraulic line in front end of the main control valve (MCV) to detect a pressure of the discharge fluid from the hydraulic pump 200, and a boom cylinder pressure sensor 222 for detecting a cylinder head pressure at a head of the boom cylinder 22. Furthermore, the control apparatus 300 may be connected to a boom angle sensor 224 for detecting a rotational angle of the boom 20 and a bucket angle sensor 234 for detecting a rotational angle of the bucket 30.

[0062] The signals detected by the sensors may be inputted into the control apparatus 100, as indicated by arrows in FIG. 2. As mentioned later, the control apparatus 300 may select one or more signals of the signals received from the sensors installed in the wheel loader 10, perform prediction algorithms obtained through training such as neural network algorithms to calculate output values representing whether or not to be within individual work load areas and analyze the output values to determine a load state of a current work or a current work state of the wheel loader 10. Further, the control apparatus 300 may output a control signal to an engine control unit (ECU), the transmission control unit (TCU) 140, and the pump control device (EPOS), etc, to selectively control the engine 100, the transmission 130, the hydraulic pump 200, etc., based on the determined work load state or work state.

[0063] Hereinafter, the control apparatus for controlling the wheel loader will be explained.

[0064] FIG. 3 is a block diagram illustrating a control apparatus for a wheel loader in accordance with example embodiments. FIG. 4 is a block diagram illustrating a signal selector, an individual load area determiner and a load state determiner of the control apparatus in FIG. 3. FIG. 5 is a view illustrating a neural network circuit in the individual load area determiner in FIG. 4. FIG. 6 is a view illustrating a signal transfer in each layer of the neural network in FIG. 5.

[0065] Referring to FIGS. 3 to 6, a control apparatus for a wheel loader 300 may include a work load determiner 310, a control signal generator 320 and a storage portion 330.

[0066] The work load determiner 310 may determine a load state of work currently performed by the wheel loader 10 or a state of work currently performed by the wheel loader 10. The control signal generator 320 may determine a control type, for example, an output torque control of an engine, an rpm control of an engine, a transmission control of a transmission, etc., based on the determined load state of the current work or the state of the current work. The storage portion 330 may store data required for learning in a predictive model and calculation in a neural network algorithm which are performed in the work load determiner 310, a control map required for determination of a control signal which is performed in the control signal generator 320, etc.

[0067] In example embodiments, the work load determiner 310 may include a signal receiver 312, a signal selector 314, an individual load area determiner 316 and a load state determiner 318.

[0068] The signal receiver 312 may receive the signals capable of representing a state of work from the sensors installed in the wheel loader 10. For example, the signal receiver 312 may receive a boom cylinder pressure signal from the boom cylinder pressure sensor 222, an FNR signal from the FNR travel lever position sensor 146, a main pressure signal from the pressure sensor 204 of the hydraulic pump 200, a vehicle speed signal from the vehicle speed sensor 132, a boom position signal from the boom angle sensor 224, a torque converter speed ratio (ratio of the number of rotations Ni of the input shaft and the number of rotations Nt of the output shaft) signal from the rotational speed sensors 122a and 122b, an accelerator pedal position signal from the accelerator pedal detection sensor 143, etc. However, it may be understood that the signals received in the signal receiver 312 may not be limited thereto, and various signals able to be used in determining a load state of work of the wheel loader or a work state of the wheel loader may be received in the signal receiver.

[0069] Further, the signal receiver 312 may receive a selection signal of an operator. The operator may operate an operation lever or a button to select a manual mode or an auto mode. When the auto mode is selected by the operator, the control apparatus for the wheel loader according to example embodiments may operate to determine the state of a current work of the wheel loader and automatically control the wheel loader.

[0070] The signal receiver 312 may include a data post processing portion. The data post processing portion may filter the inputted sensor signals to remove noise and normalize the signals.

[0071] The signal selector 314 may select one or more signals able to be used to determine whether or not a load state of work which is currently being performed by the wheel loader is within a respective one of a plurality of individual load areas, for example, a respective one of at least four individual load areas, and may output the selected signal(s) to corresponding individual determining circuits (NN_1, NN_2, NN_3, NN_4) of the individual load area determiner 316. The signal selector 314 may select one or more signals able to be used to determine whether or not the load state of work currently performed by the wheel loader is within a respective one of at least first to fourth individual load areas which are divided according to work load which consumes the power output of the engine during a series of work states. For example, the individual load areas (individual load states) may include a light load area, a medium load area, a heavy load area and an acceleration/inclined-ground load area according to the work load which consumes the power output during a series of work states performed by the wheel loader.

[0072] At least one signal selected from the group consisting of the received signals may be an indicator effectively representing a specific load state, i.e., at least one of the light load area, the medium load area, the heavy load area and the acceleration/inclined-ground load area.

[0073] The boom cylinder pressure signal may be an indicator directly representing a load state of work which is currently performed by the wheel loader, because the boom cylinder pressure signal is determined depending on a weight of sand, gravel and the like loaded in the bucket 30, a height of the boom 20, etc. The boom cylinder pressure signal may be used to determine a traveling work state and a multiple work state (traveling and boom raising work state) of a current work of the wheel loader.

[0074] The FNR signal may be an indicator distinguishing a shift between work states such as an initiation of a reverse traveling work state after an excavation work state or a swift between forward and reverse traveling work states during a traveling work state. The FNR signal may be used to determine a traveling work state and a multiple work state (traveling and boom raising work state) of a current work of the wheel loader.

[0075] The main pressure signal of the hydraulic pump, that is, an input end pressure of the MCV, may be an indicator representing an excavation work state or an operation of the boom 20 and the bucket 30, because the main pressure is maintained at a constant initial pressure when the operator does not operate the boom/bucket operation levers. The main pressure signal of the hydraulic pump may be used to determine a traveling work state, a multiple work state (traveling and boom raising work state) and an excavation work state of a current work of the wheel loader.

[0076] The vehicle speed signal may be an indicator representing a travel speed of the wheel loader. The vehicle speed signal may be used to determine a traveling work state, a multiple work state (traveling and boom raising work state) and an excavation work state of a current work of the wheel loader.

[0077] The boom position signal may be an indicator distinguishing a work state between a traveling work state, an excavation work state and a dumping work state depending on the boom position difference threrebetween. The boom position signal may be used to determine a traveling work state, a multiple work state (traveling and boom raising work state) and an excavation work state of a current work of the wheel loader.

[0078] The torque converter speed ratio may be an indicator representing the excavation work state and an inclined-ground travelling work state depending on a travel load of the wheel loader. The torque converter speed ratio may be used to determine a traveling work state, a multiple work state (travelling and boom raising work state), an excavation work state and an acceleration (inclined-ground) travelling work state.

[0079] The accelerator pedal position signal may be an indicator representing an acceleration intention of the operator. The accelerator pedal position signal may be used to determine an acceleration travelling work state.

[0080] The individual load area determiner 316 may include a plurality of the individual determining circuits. For example, the individual load area determiner 316 may include first to fourth individual determining circuits. The first to fourth individual determining circuits may calculate output values which represent whether or not to be within the first to fourth individual load areas respectively, using the selected signals. The first to fourth individual determining circuits may calculate the output signals respectively using machine learning.

[0081] Machine learning may be related to the ability to make data-driven predictions or decisions after training. For example, machine leaning may include neural networks approach, statistical approach, structural approach, fuzzy logic approach, decision tree approach, template matching approach, etc. The neural networks approach may be a method that learns mapping between inputs and outputs and processes data based on connection weights between inputs and outputs. The decision tree approach may be a method that generates a decision tree through learning and processes data based on the decision tree. Support vector machine may be used in supervised learning methods, and may be a method that, in many hyperplanes that might classify some given data, chooses the hyperplane that has the largest distance to the nearest training-data point of any class and processes data. The statistical approach may be classified into Supervised learning and Unsupervised learning. The neural networks approach may be classified into supervised learning, unsupervised learning, and reinforcement learning.

[0082] In example embodiments, the first to fourth individual determining circuits may perform prediction algorithms obtained through training to output scale values which represent the first to fourth individual load areas respectively.

[0083] The first individual determining circuit may include a light load neural network determiner NN_1 which performs neural network algorithms to calculate an output value representing as to whether or not the current work load belongs within a light load area. The light load neural network determiner NN_1 may receive the boom cylinder pressure signal, the FNR signal, the main pressure signal of the hydraulic pump, the vehicle speed signal, the boom position signal and the torque converter speed ratio signal from the signal selector 314. The light load neural network determiner NN_1 may perform neural network algorithms to calculate a first output value representing whether or not a load area of work currently performed by the wheel loader is within the light load area. For example, the first output value may be a probability value representing whether or not the current work load corresponds to the light load state. The first output value may be quantified as a number between 0 and 1.

[0084] The second individual determining circuit may include a medium load neural network determiner NN_2 which performs neural network algorithms to calculate an output value representing as to whether or not the current work load belongs within a medium load area. The medium load neural network determiner NN_2 may receive the main pressure signal of the hydraulic pump, the vehicle speed signal, the boom position signal and the torque converter speed ratio signal from the signal selector 314. The medium load neural network determiner NN_2 may perform neural network algorithms to calculate a second output value representing whether or not a load area of work currently performed by the wheel loader is within the medium load area. For example, the second output value may be a probability value representing whether or not the current work load corresponds to the medium load state.

[0085] The third individual determining circuit may include a heavy load neural network determiner NN_3 which performs neural network algorithms to calculate an output value representing as to whether or not the current work load belongs within a heavy load area. The heavy load neural network determiner NN_3 may receive the boom cylinder pressure signal, the FNR signal, the main pressure signal of the hydraulic pump, the vehicle speed signal, the boom position signal and the torque converter speed ratio signal from the signal selector 314. The heavy load neural network determiner NN_3 may perform neural network algorithms to calculate a third output value representing whether or not a load area of work currently performed by the wheel loader is within the heavy load area. For example, the third output value may be a probability value representing whether or not the current work load corresponds to the heavy load state.

[0086] The fourth individual determining circuit may include an acceleration/inclined-ground load neural network determiner NN_4 which performs neural network algorithms to calculate an output value representing as to whether or not the current work load belongs within an acceleration/inclined-ground load area. The acceleration/inclined-ground load neural network determiner NN_4 may receive the torque converter speed ratio and the accelerator pedal position signal from the signal selector 314. The acceleration/inclined-ground load neural network determiner NN_4 may perform neural network algorithms to calculate a fourth output value representing whether or not a load area of work currently performed by the wheel loader is within the acceleration/inclined-ground load area. For example, the fourth output value may be a probability value representing whether or not the current work load corresponds to the acceleration/inclined-ground load state.

[0087] In example embodiments, the light load neural network determiner NN_1, the medium load neural network determiner NN_2, the heavy load neural network determiner NN_3 and the acceleration/inclined-ground neural network determiner NN_4 may include neural network circuits that performs neural network algorithms and calculates an output value representing an individual load state, respectively.

[0088] As illustrated in FIGS. 5 and 6, the neural network circuit may include multilayer perceptrons having a multi-input layer, a hidden layer and an output layer. Neurons may be arranged in each layer, and the neurons in each layer may be connected by connection weights. Input data may be inputted to the neurons in the input layer and transferred to the output layer though the hidden layer.

[0089] Training the neural network algorithm may be a process of tuning the interconnection weights between each nodes in order to minimize an error between an expectation value and an output value of the neural network algorithms for a specific input (actual detected data). For example, backpropagation algorithm may be used for training the neural networks. Accordingly, the neural network circuits of the individual neural network determiners (NN_1, NN_2, NN_3, NN_4) may vary the connection weights between the input layer, the hidden layer and the output layer using the collected data to provide neural network algorithms as prediction models.

[0090] Thus, the neural network circuit may perform the neural network algorithms obtained through training and calculate an output value which represents the individual load state.

[0091] The load state determiner 318 may analyze the output values from the first to fourth individual determining circuits to determine a load state of work currently performed by the wheel loader 10 or a state of work currently performed by the wheel loader 10. The load state determiner 318 may perform post-processing such as weighted applications on the output values from the individual neural network determiners (NN_1, NN_2, NN_3, NN_4) and output a final result value.

[0092] For example, the load state determiner 318 may analyze the output values to determine a current load state of work currently performed by the wheel loader 10. Accordingly, the load state determiner 318 may determine which one of the light load state, the medium load state, the heavy load state and the acceleration/inclined-ground load state is the load state of work currently performed by the wheel loader 10.

[0093] The load state determiner 318 may consider additional signals received from other sensors to determine a current state of work currently performed by the wheel loader 10. Accordingly, the load state determiner 318 may determine a current load state or a current work state of the wheel loader 10.

[0094] The control signal generator 320 may output a control signal based on the determined current load state or the determined current work state of the wheel loader 10. The control signal may be used to selectively control the engine 100, the transmission 130, the hydraulic pump 200, etc. For example, the control signal generator 320 may output a control signal for controlling engine output torque, engine rpm, transmission speed step, transmission timing, etc.

[0095] Accordingly, the control signal generator 320 may control the engine 100 and the transmission 130 based on the finally determined work load state or work state to thereby improve operating performance and fuel efficiency.

[0096] The storage portion 330 may include a first storage portion 332 connected to the work load determiner 310 and storing data required to determine a work load state, and a second storage portion 334 connected to the control signal generator 320 and storing data required to generate the control signal. The first storage portion 332 may store data required for training and performing the neural network algorithms. The second storage portion 334 may store engine torque map, engine rpm map, transmission swift control map, etc., required for determining the control signal.

[0097] As mentioned above, the control apparatus for a wheel loader may select signals capable of effectively representing the individual load state (light load area, medium load area, heavy load area, acceleration/inclined-ground load area) of signals received from sensors installed in the wheel loader 10 and determine a load state of a current work or a current work state by using prediction algorithms obtained through training such as neural network algorithms.

[0098] Thus, the time and burden spent on calculations in order to determine a load state of work currently performed by the wheel loader may be reduced and the accuracy of the determinations may be improved. Further, the engine and the transmission may be controlled based on the finally determined work load state to thereby improve operating performance and fuel efficiency.

[0099] Hereinafter, a method of controlling a wheel loader using the control apparatus in FIG. 3 will be explained.

[0100] FIG. 7 is a flow chart illustrating a method of controlling a wheel loader in accordance with example embodiments.

[0101] Referring to FIGS. 3, 4 and 7, first, signals representing a state of work currently performed by a wheel loader (S100).

[0102] The control apparatus for a wheel loader 300 may receive signals capable of representing a work state from sensors installed in the wheel loader. For example, the signal receiver 312 of the work load determiner 310 may receive a boom cylinder pressure signal, an FNR signal, a main pressure signal of a hydraulic pump, a vehicle speed signal, a boom position signal, a torque converter speed ratio signal, an accelerator pedal position signal, etc.

[0103] Then, one or more signals able to be used to determine whether or not to be within a respective one of a plurality of individual load areas, of the received signals may be selected (S110).

[0104] The signal selector 314 may select one or more signals able to be used to determine whether or not the current work state is within a respective one of at least first to fourth individual load areas and output the selected signal to corresponding individual determining circuits (NN_1, NN_2, NN_3, NN_4) of the individual load area determiner 316.

[0105] The first to fourth individual load areas (individual load states) may correspond to a light load area, a medium load area, a heavy load area and an acceleration/inclined-ground load area according to work load which consumes the power output during a series of work states performed by the wheel loader. The received signals may be classified according to whether the signal effectively represents a specific load state, i.e., at least one of the light load area, the medium load area, the heavy load area and the acceleration/inclined-ground load area.

[0106] For example, the boom cylinder pressure signal, the FNR signal, the main pressure signal of the hydraulic pump, the vehicle speed signal, the boom position signal and the torque converter speed ratio signal of the received signals may be used to determine whether or not to be within the light load area and the heavy load area of the wheel loader, and thus may be inputted into the light load neural network NN_1 and the heavy load neural network NN_3 of the individual load area determiner 316.

[0107] The main pressure signal of the hydraulic pump, the vehicle speed signal, the boom position signal and the torque converter speed ratio signal may be used to determine whether or not to be within the medium load area, and thus may be inputted into the medium load neural network determiner NN_2 of the individual load area determiner 316.

[0108] The torque converter speed ratio signal and the accelerator pedal position signal may be used to determine whether or not to be within the acceleration/inclined-ground load area, and thus may be inputted into the acceleration/inclined-ground neural network determiner NN_4 of the individual load area determiner 316.

[0109] Then, neural network algorithms obtained through training may be performed on the selected signals to determine whether or not to be within the respective one of the plurality of the individual load areas (S120).

[0110] The light load neural network determiner NN_1, the medium load neural network determines NN_2, the heavy load neural network determiner NN_3 and the acceleration/inclined-ground neural network determiner NN_4 of the individual load area determiner 316 may perform neural network algorithms on the selective signals to calculate output values representing as to whether or not the current work load belongs within the light load area, the medium load area, the heavy load area and the acceleration/inclined-ground load area respectively.

[0111] Then, the output values may be analyzed to determine a load state of work currently performed by the wheel loader (S130).

[0112] The load state determiner 318 may analyze the output values to determine which one of the light load state, the medium load state, the heavy load state and the acceleration/inclined-ground load state is the load state of work currently performed by the wheel loader 10.

[0113] The load state determiner 318 may consider additional signals received from other sensors to determine a current state of work currently performed by the wheel loader 10.

[0114] Then, an engine, a transmission, a hydraulic pump, etc. of the wheel loader may be selectively controlled in consideration of the current load sate or the current work state of the wheel loader.

[0115] Hereinafter, a method of determining a load state of a series of work states in V-shape driving of a wheel loader using the control method in FIG. 7 will be explained.

[0116] FIG. 8 is a view illustrating V-shape driving of a wheel loader in accordance with example embodiments. FIG. 9 is graphs illustrating output values representing whether or not to be within a respective one of individual load areas in each work state in the V-shape driving of FIG. 8. FIG. 10 is a graph illustrating a final load state obtained from the output values of FIG. 9. For your reference, FIGS. 9 and 10 include a graph of a boom cylinder pressure versus time in the V-shape driving.

[0117] Referring to FIGS. 8 to 10, a wheel loader 10 may perform V-shape driving which is one of driving methods to load a subject material such as sand (S) into a dump truck (T). In the V-shape driving, the wheel loader 10 may perform sequentially a series of work states, i.e., a forward travelling work state (a), an excavation work state (b), a reverse travelling work state (c), a forward travelling and boom raising work state (d), a dumping work state (e), and a reverse travelling and boom down work state (f).

[0118] As illustrated in FIG. 9, whether or not to be within individual load areas may be determined for each work state in the V-shape driving. A light load neural network determiner NN_1 may calculate an output value representing as to whether or not to be within a light load area with respect to a series of the work states (a~f). A medium load neural network determiner NN_2 may calculate an output value representing as to whether or not to be within a medium load area with respect to a series of the work states (a~f). A heavy load neural network determiner NN_3 may calculate an output value representing as to whether or not to be within a heavy load area with respect to a series of the work states (a~f). An acceleration/inclined-ground load neural network determiner NN_4 may calculate an output value representing as to whether or not to be within a heavy load area with respect to a series of the work states (a~f).

[0119] As illustrated in FIG. 10, the output values may be synthetically analyzed to determine a load state of work currently being performed by the wheel loader 10. A load state determiner 318 may determine which one of the light load state, the medium load state, the heavy load state and the acceleration/inclined-ground load state is the load state of a series of the work states (a~f) currently performed by the wheel loader 10.

[0120] In the V-shape driving of the wheel loader, the forward travelling work state (a), the reverse travelling work state (c) and the reverse travelling and boom down work state (f) may be determined as the light load state, the excavation work state (b) may be determined as the medium load state, and the forward travelling and boom raising work state (d) may be determined as the heavy load state. Further, an inclined-ground travelling work state and an acceleration travelling work state of the work states performed by the wheel loader may be determined as the acceleration/inclined-ground load state.

[0121] The wheel loader may operate in a selected mode of a plurality of power modes. For example, the power modes may include economy mode (E-mode), standard mode (S-mode) and power mode (P-mode). Each power mode may have a predetermined engine torque map. When the operator selects the manual mode, an engine may be controlled according to a predetermined manual engine torque map in the manual mode. On the other hand, when the operator selects the auto mode, the control apparatus according to example embodiments may output a control signal for controlling an engine or a transmission of the wheel loader based on a current load state of the wheel loader and then a power of the engine or the transmission may be automatically selected according to the control signal. In this case, the engine may be controlled according to a predetermined auto engine torque map in the auto mode.

[0122] As illustrated in FIGS. 11A to 11C, the manual engine torque maps for power modes in the manual mode may be different from the auto engine torque map for power modes in the auto mode.

[0123] While example embodiments have been particularly shown and described with the V-shape driving, it will be understood that the present inventive concept may be applied to various other driving, e.g., load and carry driving, I-cross driving, etc.

[0124] The foregoing is illustrative of example embodiments of the invention and is not to be construed as limiting thereof. Although a few example embodiments have been described, those skilled in the art will readily appreciate that many modifications are possible in the example embodiments without materially departing from the novel teachings and advantages of the present inventive concept. Accordingly, all such modifications are intended to be included within the scope of the present inventive concept as defined in the claims. Therefore, it is to be understood that the foregoing is illustrative of various example embodiments and is not to be construed as limited to the specific example embodiments disclosed, and that modifications to the disclosed example embodiments, as well as other example embodiments, are intended to be included within the scope of the appended claims.

Claims

1. A method of controlling a wheel loader, comprising:

    receiving signals representing a state of work currently performed by the wheel loader, from sensors installed in the wheel loader;
    selecting one or more signals of the received signals, the one or more signals able to be used to determine whether or not to be within a respective one of a plurality of individual load areas, wherein the individual load areas are divided according to work load which consumes a power output of an engine during a series of work states performed by the wheel loader;
    calculating output values representing as to whether or not to be within the respective one of the plurality of individual load areas, by using the selected signal; and
    analyzing the output values to determine a current load state of the work currently performed by the wheel loader.

2. The method of claim 1, wherein calculating the output values comprises using machine learning to calculate the output values.

3. The method of claim 2, wherein machine leaning comprises any one selected from the group consisting of neural networks approach, statistical approach, structural approach, fuzzy logic approach, decision tree approach and template matching approach.

4. The method of claim 1, wherein calculating the output values comprises using a table stored in a memory by a wheel loader manufacturer to calculate the output values.

5. The method of claim 1, wherein calculating the output values comprises performing prediction algorithms obtained through training on the selected signal to calculate the output values.

6. The method of claim 5, wherein the prediction algo-

rithm comprises connection weights between an input layer, a hidden layer and an output layer.

7. The method of claim 1, wherein calculating the output values comprises calculating an output value representing as to whether or not to be within a light load area, calculating an output value representing as to whether or not to be within a medium load area, calculating an output value representing as to whether or not to be within a heavy load area and calculating an output value representing as to whether or not to be within an acceleration/inclined-ground load area.

8. The method of claim 7, wherein at least one of a boom cylinder pressure signal, an FNR signal, a main pressure signal of a hydraulic pump, a vehicle speed signal, a boom position signal and a torque converter speed ratio signal is used to determine whether or not to be within the light load area and the heavy load area of the wheel loader, at least one of the main pressure signal of the hydraulic pump, the vehicle speed signal, a boom position signal and the torque converter speed ratio signal is used to determine whether or not to be within the medium load area of the wheel loader.

9. The method of claim 7, wherein at least one of a torque converter speed ratio signal and an accelerator pedal position signal is used to determine whether or not to be within the acceleration/inclined-ground load area of the wheel loader.

10. The method of claim 7, wherein a forward travelling work state, a reverse travelling work state and a reverse travelling and boom down work state in a V-shape driving of the wheel loader are determined as a light load state, an excavation work state is determined as a medium load state, and a forward travelling and boom raising work state is determined as a heavy load state.

11. The method of claim 1, further comprising outputting a control signal for controlling an engine or a transmission of the wheel loader according to the current load state of the wheel loader.

12. An apparatus for controlling a wheel loader, comprising:

a signal receiver configured to receive signals representing a state of work currently performed by the wheel loader, from sensors installed in the wheel loader;
a signal selector configured to provide a plurality of individual load areas according to work load which consumes a power output of an engine during a series of work states performed by the wheel loader and configured to select one or more signals of the received signals, the one or more signals able to be used to determine whether or not to be within a respective one of the plurality of individual load areas;
an individual load area determiner configured to calculate output values representing as to whether or not to be within the respective one of the plurality of individual load areas, by using the selected signal; and
a load state determiner configured to analyze the output values to determine a current load state of the work currently performed by the wheel loader.

13. The apparatus of claim 12, wherein the individual load area determiner comprises individual calculating circuits which calculate the output values using machine learning, and machine leaning comprises any one selected from the group consisting of neural networks approach, statistical approach, structural approach, fuzzy logic approach, decision tree approach and template matching approach.

14. The apparatus of claim 12, wherein the individual load area determiner performs prediction algorithms obtained through training on the selected signal to calculate the output values.

15. The apparatus of claim 12, wherein the individual load area determiner comprises a light load determining circuit which calculates an output value representing as to whether or not to be within a light load area, a medium load determining circuit which calculates an output value representing as to whether or not to be within a medium load area, a heavy load determining circuit which calculates an output value representing as to whether or not to be within a heavy load area, and an acceleration/inclined-ground determining circuit which calculates an output value representing as to whether or not to be within an acceleration/inclined-ground load area.

16. The apparatus of claim 12, wherein the light load determining circuit and the heavy load determining circuit use at least one of a boom cylinder pressure signal, an FNR signal, a main pressure signal of a hydraulic pump, a vehicle speed signal, a boom position signal and a torque converter speed ratio signal to determine whether or not to be within the light load area and the heavy load area of the wheel loader, the medium load determining circuit uses at least one of the main pressure signal of the hydraulic pump, the vehicle speed signal, a boom position signal and the torque converter speed ratio signal to determine whether or not to be within the medium load area of the wheel loader.

17. The apparatus of claim 12, wherein the load state determiner determines a forward travelling work state, a reverse travelling work state and a reverse travelling and boom down work state in a V-shape driving of the wheel loader as a light load state, determines an excavation work state as a medium load state, and determines a forward travelling and boom raising work state determined as a heavy load state.

FIG. 1

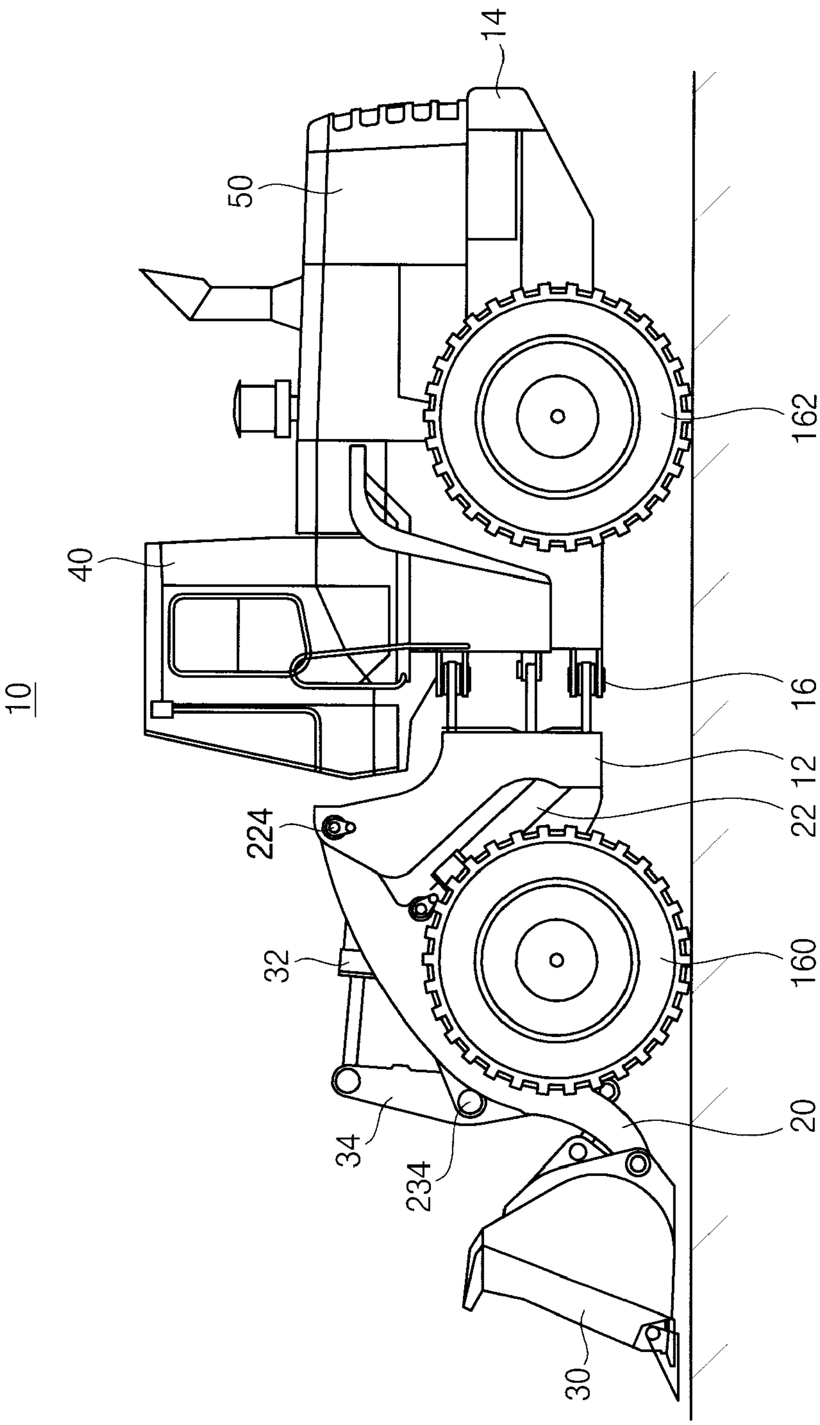


FIG. 2

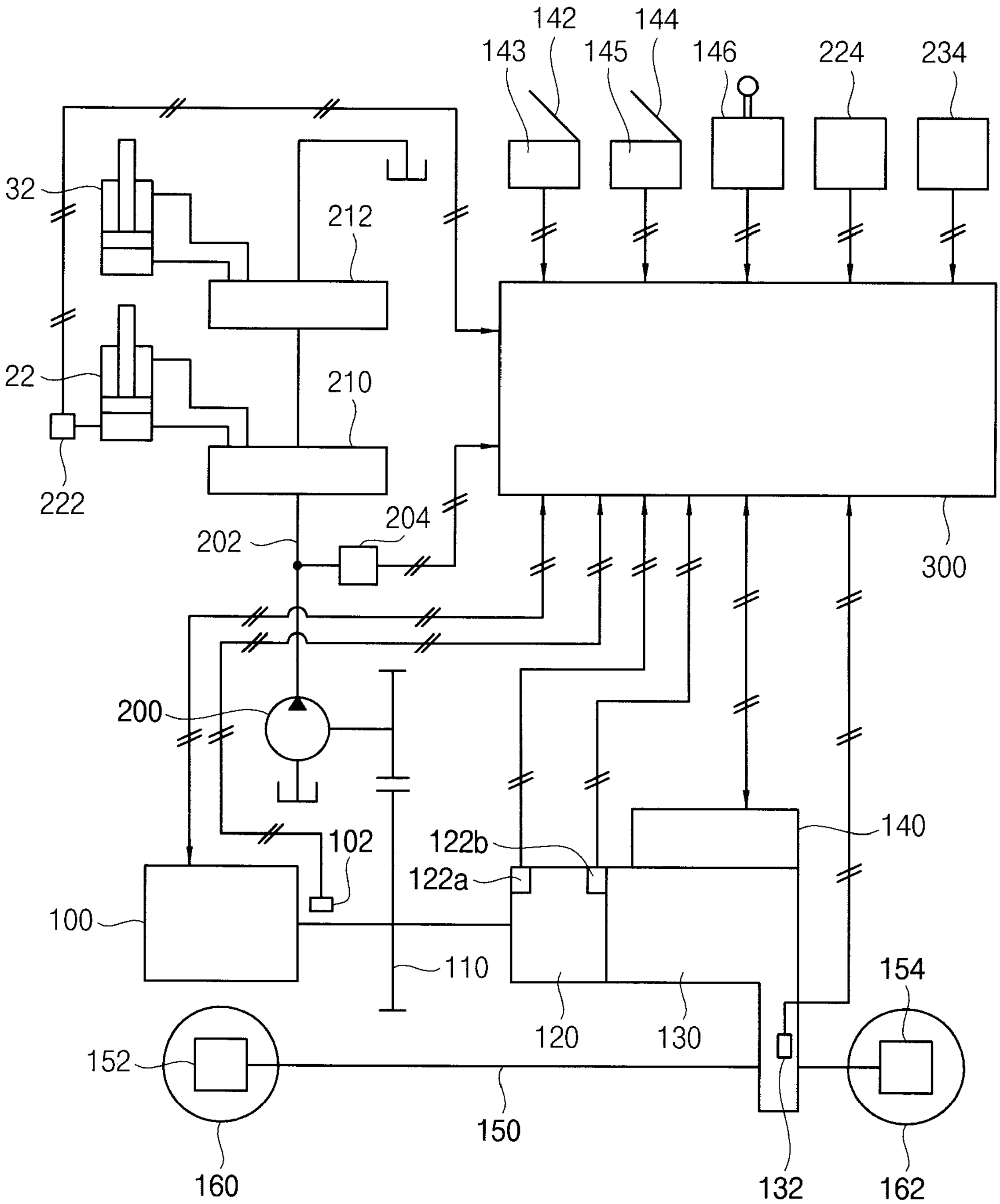

142
144
143
145
146
224
234
32
212
22
210
222
204
202
300
200
102
122b
140
122a
100
110
154
120
130
152
150
160
132
162

FIG. 3

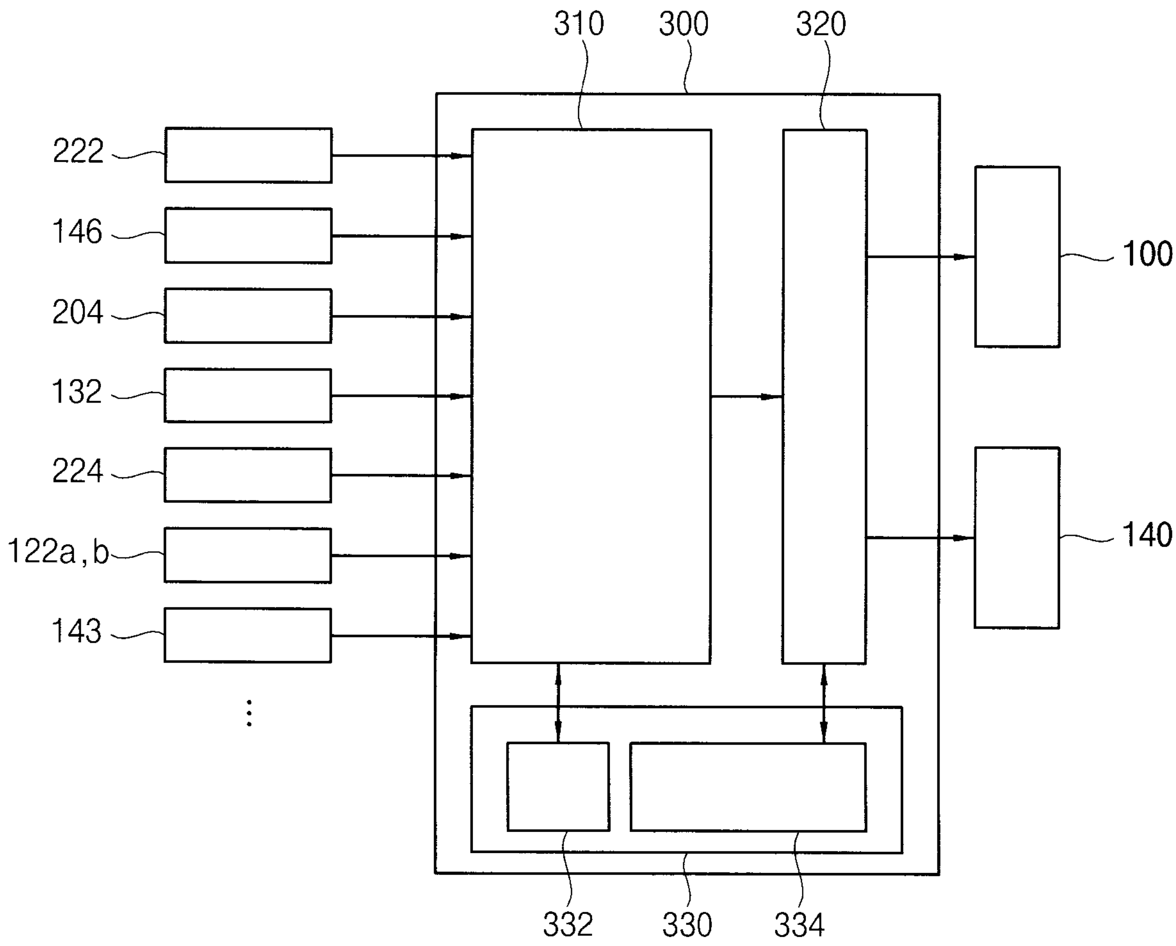


FIG. 4

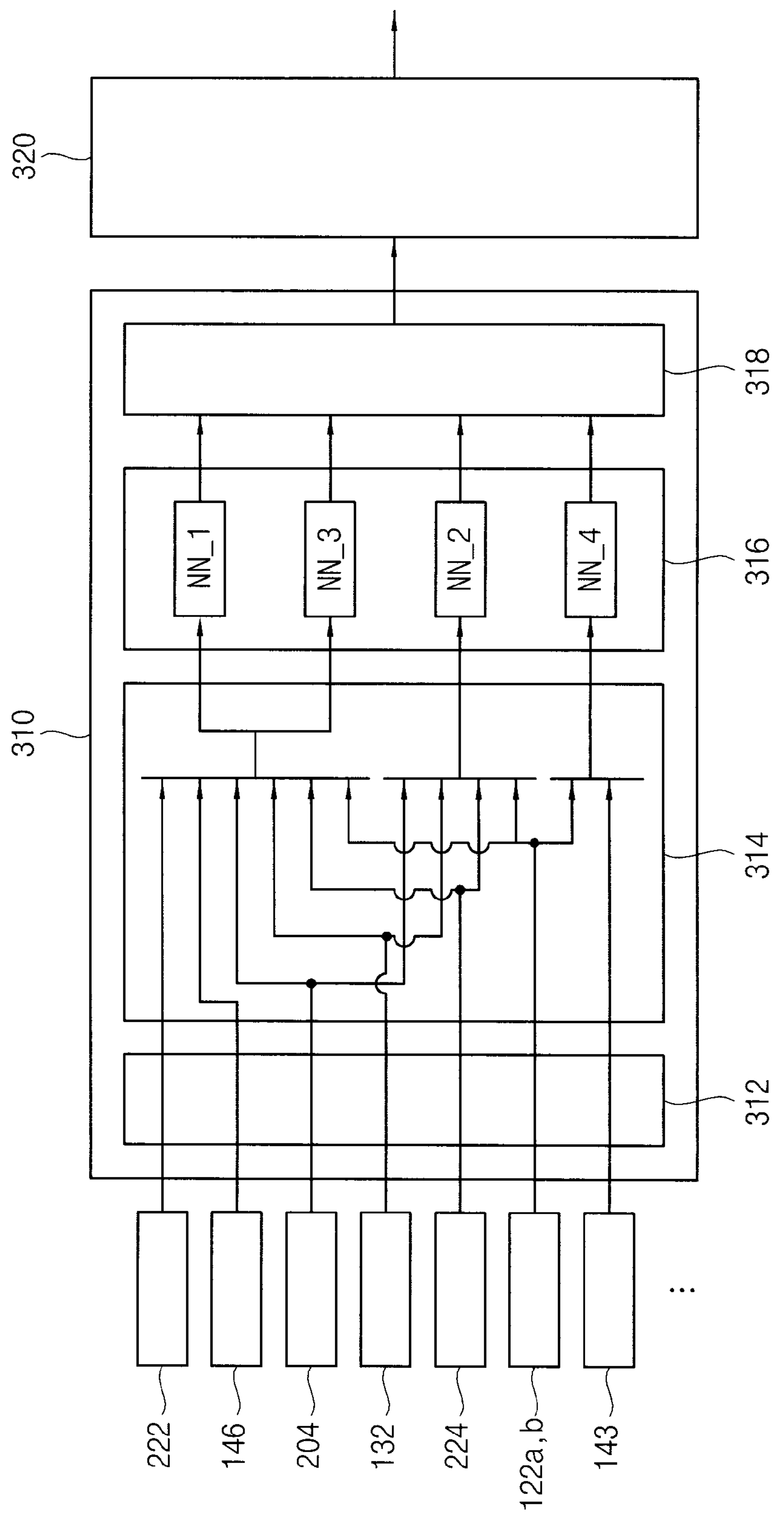

320
318
316
314
312
310
NN_1
NN_3
NN_2
NN_4
222
146
204
132
224
122a,b
143
...

FIG. 5

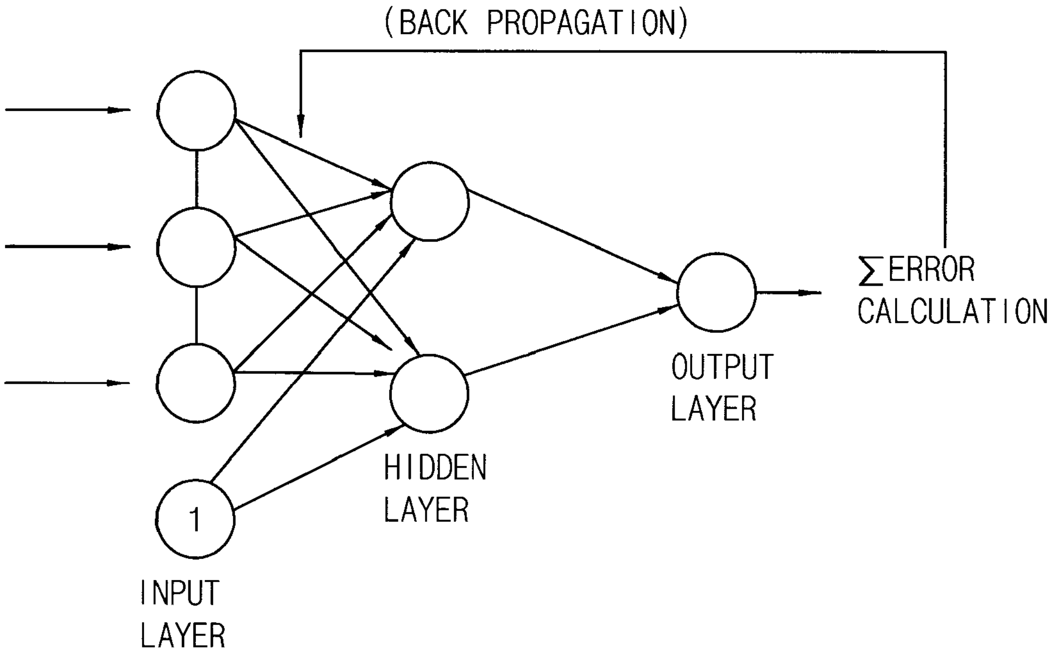

(BACK PROPAGATION)
1
INPUT LAYER
HIDDEN LAYER
OUTPUT LAYER
∑ERROR CALCULATION

FIG. 6

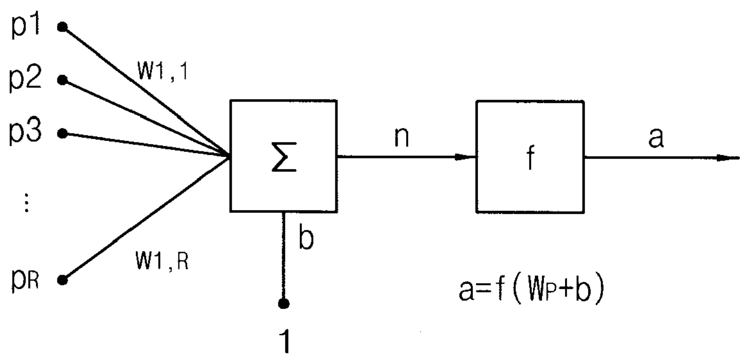


FIG. 7

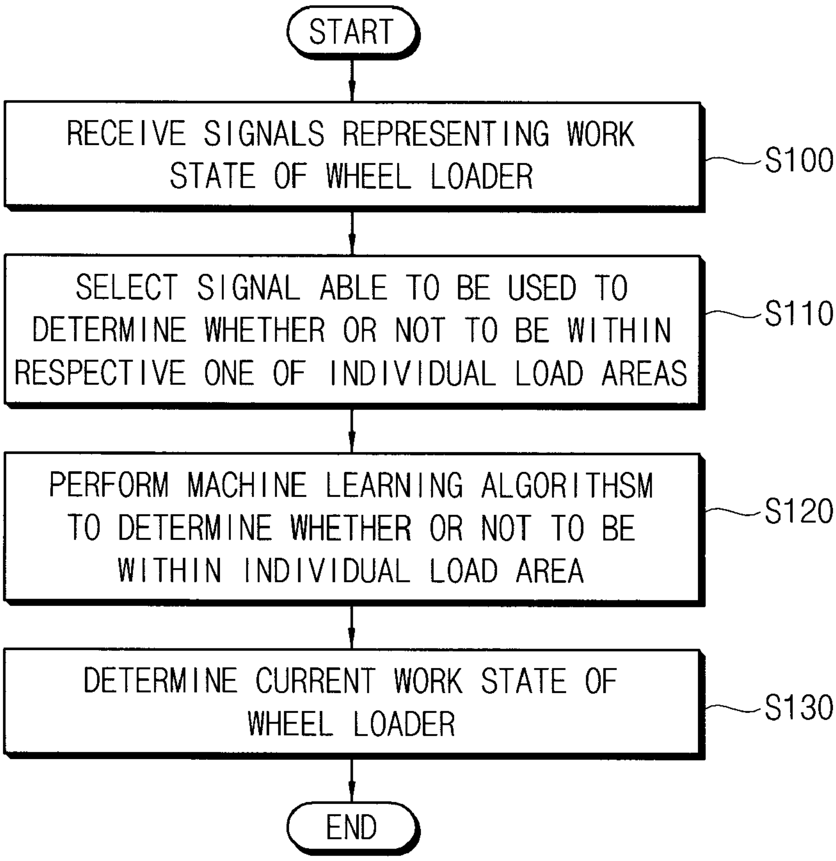

START
RECEIVE SIGNALS REPRESENTING WORK STATE OF WHEEL LOADER
S100
SELECT SIGNAL ABLE TO BE USED TO DETERMINE WHETHER OR NOT TO BE WITHIN RESPECTIVE ONE OF INDIVIDUAL LOAD AREAS
S110
PERFORM MACHINE LEARNING ALGORITHSM TO DETERMINE WHETHER OR NOT TO BE WITHIN INDIVIDUAL LOAD AREA
S120
DETERMINE CURRENT WORK STATE OF WHEEL LOADER
S130
END

FIG. 8

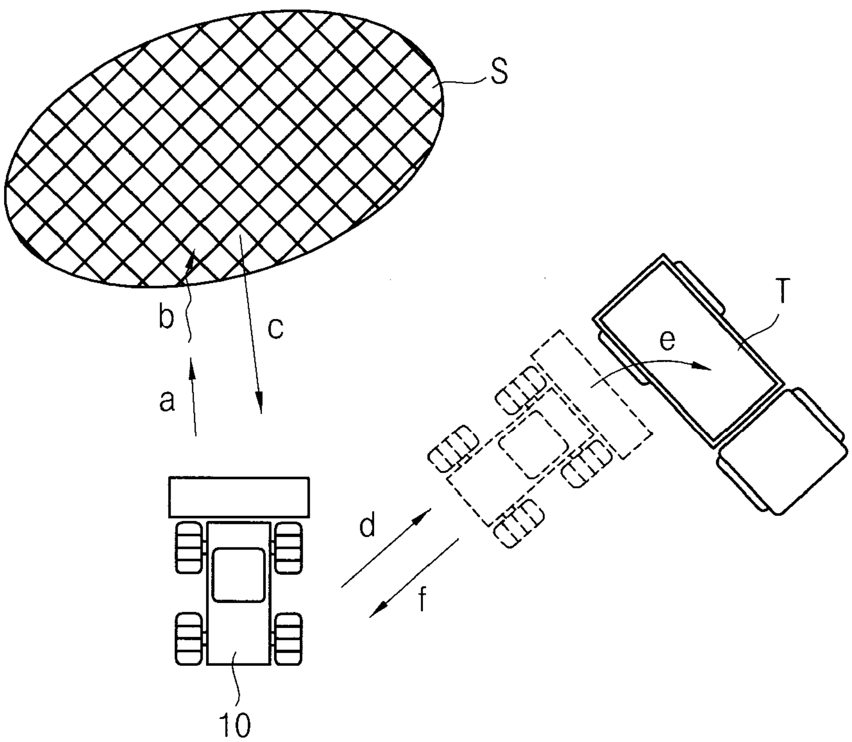


FIG. 9

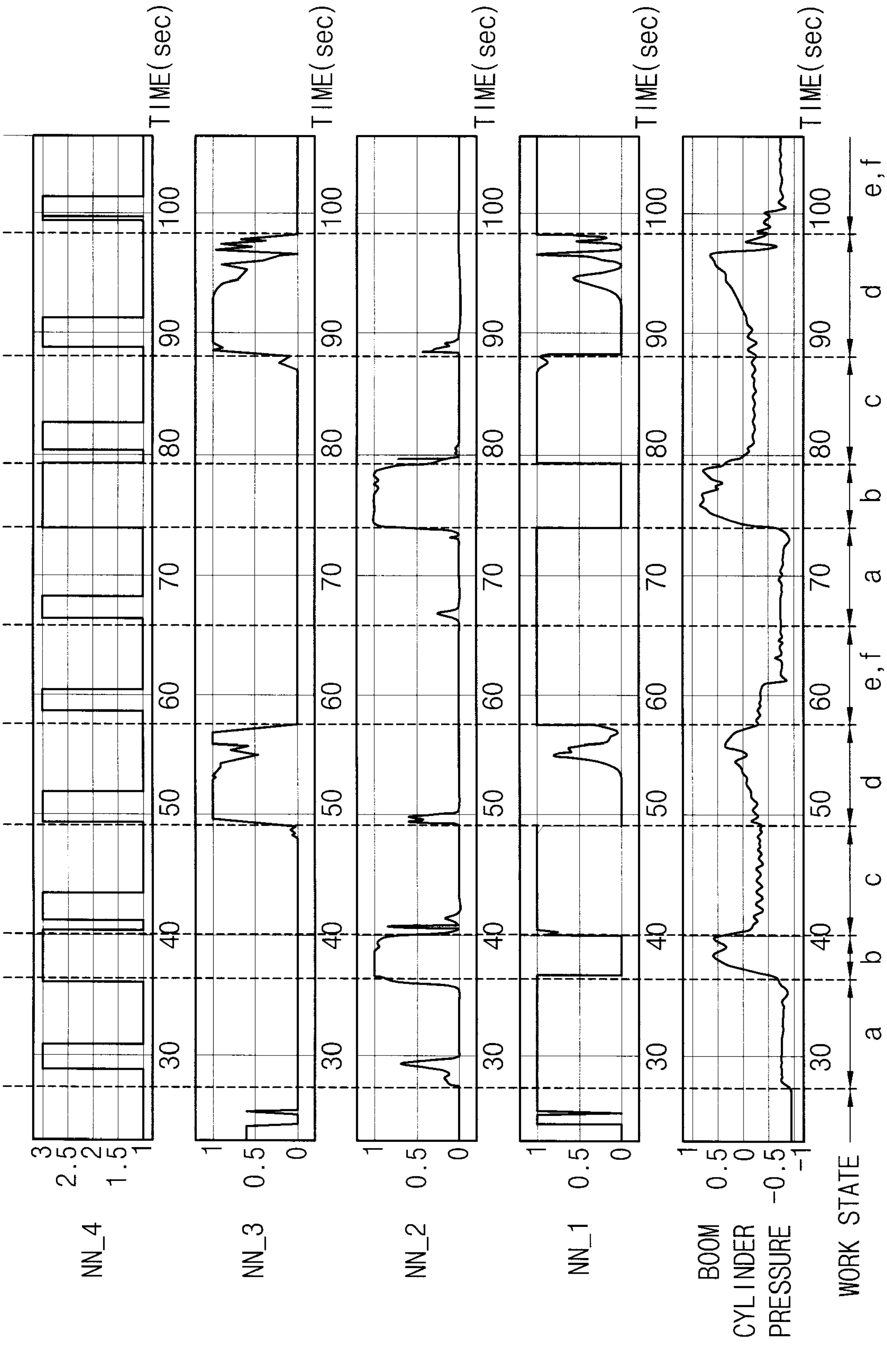

NN_4
NN_3
NN_2
NN_1
BOOM CYLINDER PRESSURE
WORK STATE
TIME(sec)
30
40
50
60
70
80
90
100
a
b
c
d
e,f

FIG. 10

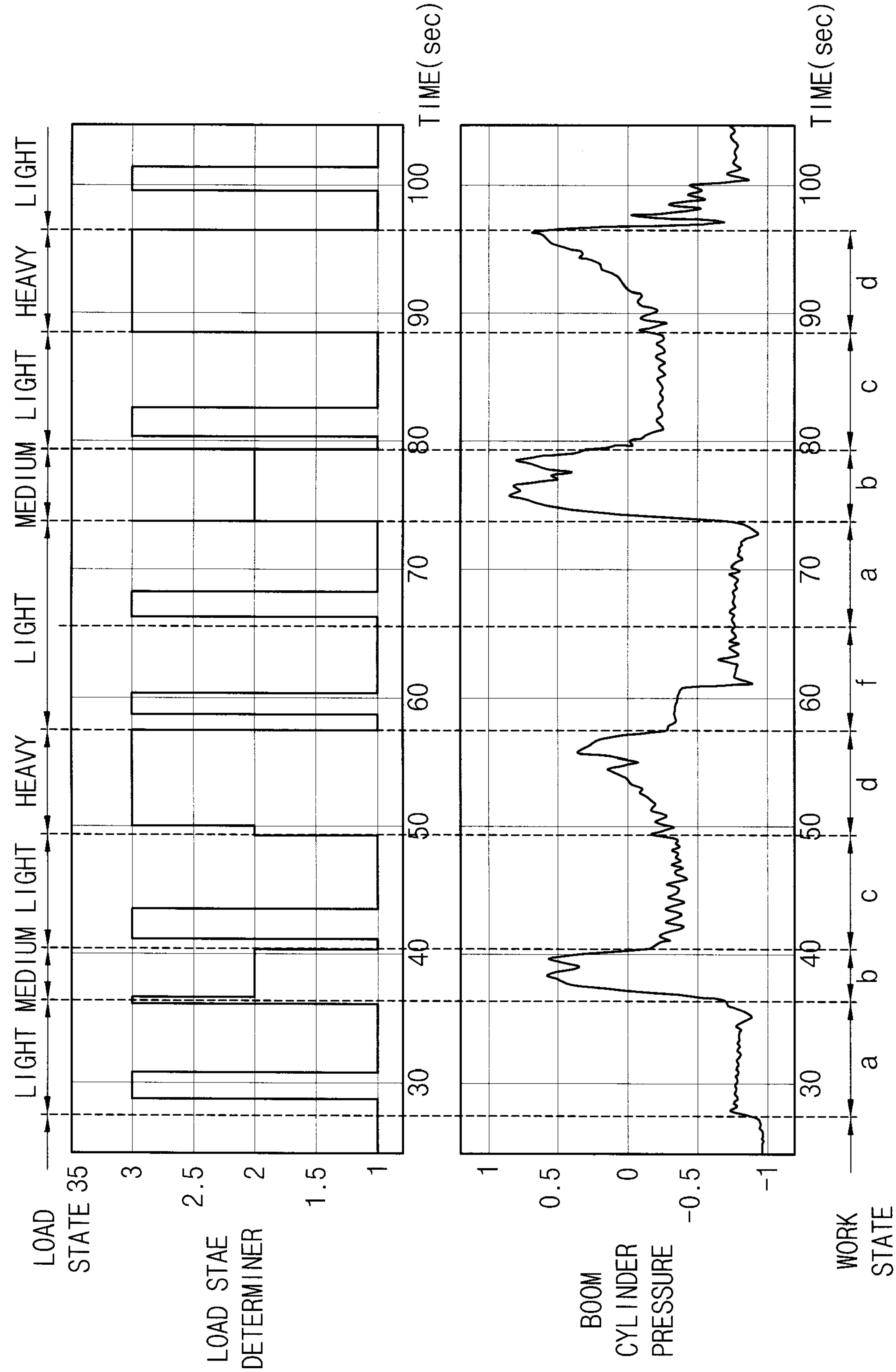

LOAD STATE
LIGHT
MEDIUM
LIGHT
HEAVY
LIGHT
MEDIUM
LIGHT
HEAVY
LIGHT
LOAD STAE DETERMINER
35
3
2.5
2
1.5
1
BOOM CYLINDER PRESSURE
1
0.5
0
-0.5
-1
30
40
50
60
70
80
90
100
TIME(sec)
WORK STATE
a
b
c
d
f
a
b
c
d

FIG. 11A

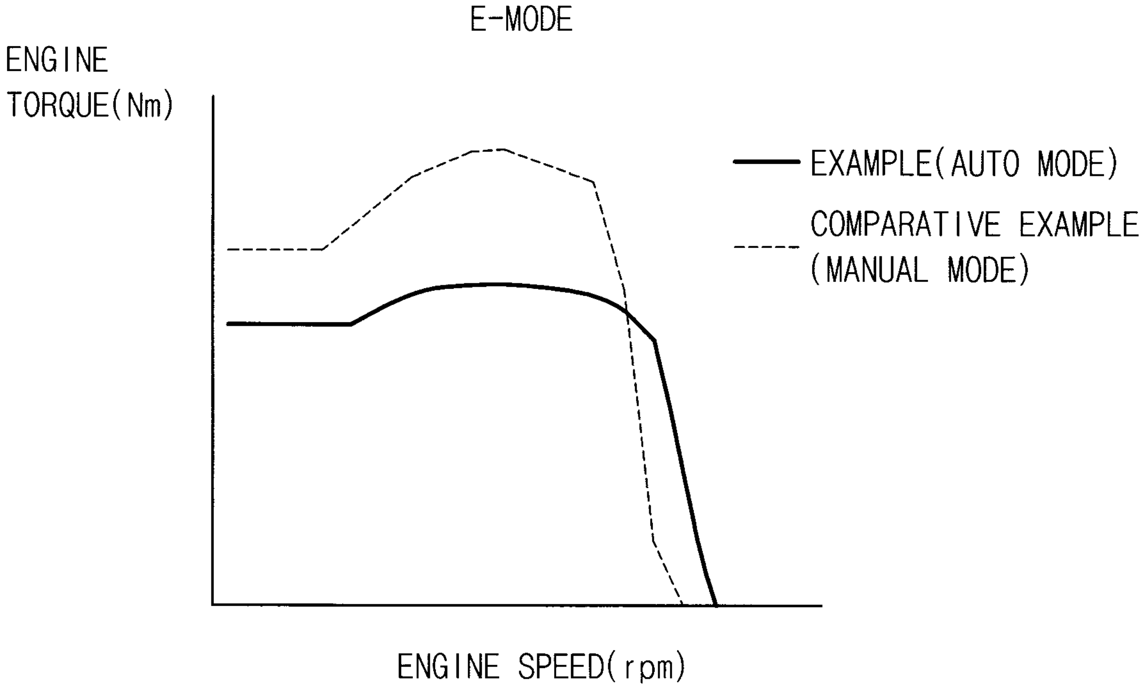

E-MODE
ENGINE
TORQUE(Nm)
EXAMPLE(AUTO MODE)
COMPARATIVE EXAMPLE
(MANUAL MODE)
ENGINE SPEED(rpm)

FIG. 11B

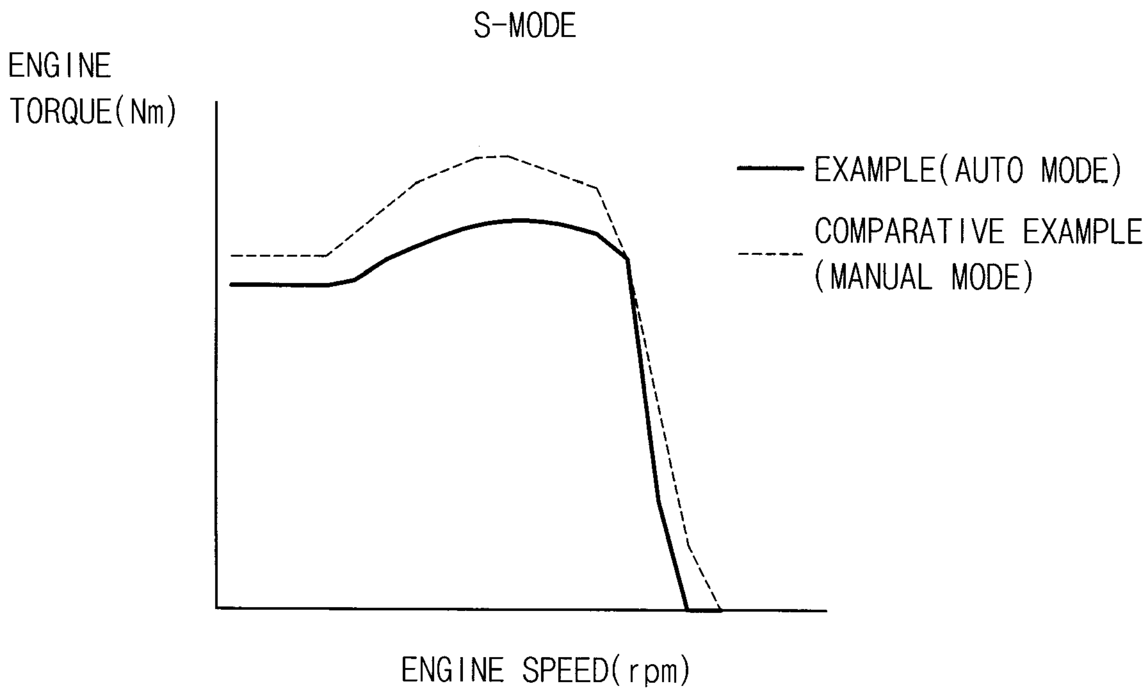
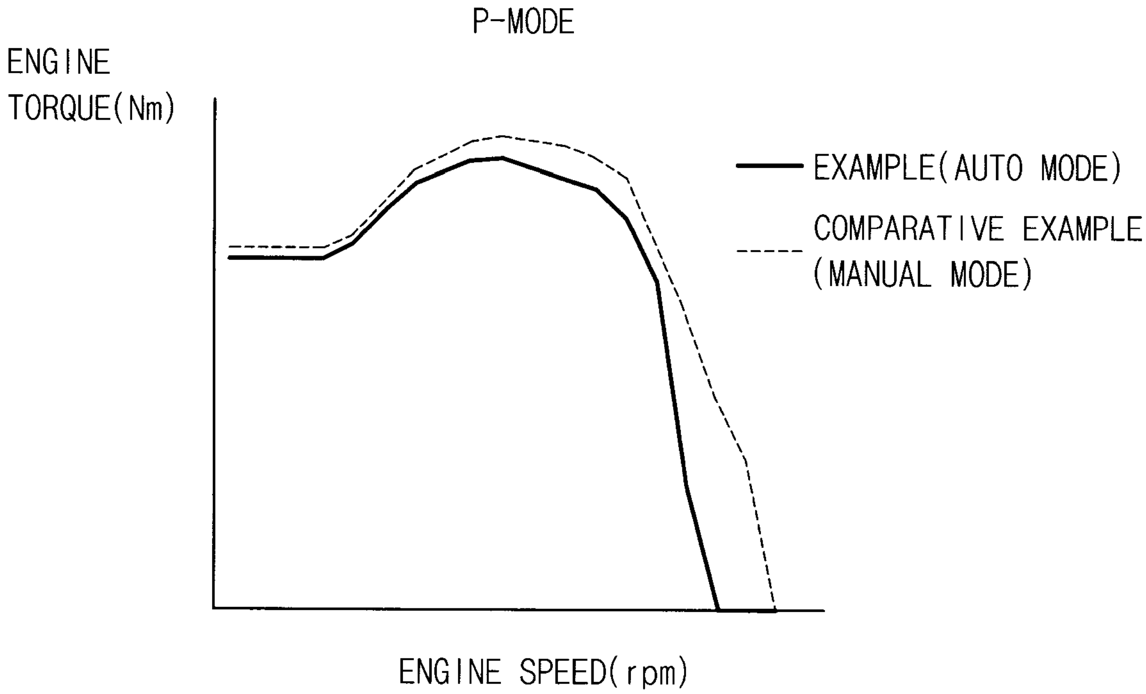

S-MODE
ENGINE
TORQUE(Nm)
EXAMPLE(AUTO MODE)
COMPARATIVE EXAMPLE
(MANUAL MODE)
ENGINE SPEED(rpm)

FIG. 11C


P-MODE
ENGINE
TORQUE(Nm)
EXAMPLE(AUTO MODE)
COMPARATIVE EXAMPLE
(MANUAL MODE)
ENGINE SPEED(rpm)

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 16 16 9390

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y X,P Y,P	WO 2014/098391 A1 (DOOSAN INFRACORE CO LTD [KR]) 26 June 2014 (2014-06-26) * abstract * & US 2015/159347 A1 (PARK KWANG SEOK [KR] ET AL) 11 June 2015 (2015-06-11) * the whole document * -----	1-4,7-17 5,6 1-4,7-17 5,6	INV. E02F9/08 E02F9/22 B60W20/11 E02F9/20
X	US 6 618 658 B1 (KAGOSHIMA MASAYUKI [JP] ET AL) 9 September 2003 (2003-09-09) * figures * -----	1,12	
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