

DESCRIPTION

Title of Invention

ASSISTANCE DEVICE, ASSISTANCE METHOD, AND PROGRAM

Technical Field

[0001]

The present invention relates to an assistance device, an assistance method, and a program.

Background Art

[0002]

In the related art, a device for assisting the operation of a plant is widely known. For example, the device described in PTL 1 has a prediction model that is trained by machine learning using a plurality of results obtained by simulating a plurality of states of a manufacturing device as teacher data, and inputs at least a part of information related to a first state of the manufacturing device into the prediction model to calculate a second state of the manufacturing device. The first state of the manufacturing device is a physical quantity that can be directly measured by a sensor or the like, and the second state of the manufacturing device is a physical quantity that is extremely difficult to be directly

measured by a sensor or the like. Then, the image information inside the manufacturing device that is difficult to observe is generated based on the calculation result of the information related to the second state of the manufacturing device, and the generated image information is displayed.

[0003]

In addition, the device described in PTL 2 calculates simulation data in a case where each of the history data of a model parameter is applied, and searches for a desired model parameter from the history data such that the degree of coincidence between the simulation data and the output of an actual plant is increased.

Citation List

Patent Literature

[0004]

[PTL 1] Japanese Unexamined Patent Publication No.
2018-169818

[PTL 2] Japanese Unexamined Patent Publication No.
2010-225022

Summary of Invention

Technical Problem

[0005]

However, in the related art, a processing load when information related to the flowing state of a material inside the plant is output has not been studied, and improvement thereof has been required.

[0006]

The present invention has been made in view of such circumstances, and an object of the present invention is to provide an assistance device, an assistance method, and a program capable of reducing a processing load when information related to a flowing state of a material inside a plant is output.

Solution to Problem

[0007]

In order to solve the above problem, an assistance device according to an aspect of the present invention is an assistance device to assist an operation of a plant, the assistance device including a storage unit that stores reference data in which an analysis condition including an operation manipulated variable of the plant and an analysis result corresponding to the analysis condition are associated with each other, the analysis result including information indicating a flowing state of a circulation material inside the plant, an acquisition unit that acquires operation data including the operation manipulated

variable in an operation state of the plant and a sensor value detected by a sensor provided in the plant, and an output unit that outputs reference information related to the reference data corresponding to the operation data, based on the reference data and the operation data.

[0008]

According to an aspect of the present invention, there is provided an assistance method for assisting an operation of a plant, the assistance method including storing reference data in which an analysis condition including an operation manipulated variable of the plant and an analysis result corresponding to the analysis condition and including information indicating a flowing state of a circulation material inside the plant are associated with each other, acquiring operation data including the operation manipulated variable in an operation state of the plant and a sensor value detected by a sensor provided in the plant, and outputting reference information related to the reference data corresponding to the operation data, based on the reference data and the operation data.

[0009]

According to an aspect of the present invention, there is provided a program causing a computer to execute a process including storing reference data in which an analysis condition including an operation manipulated

variable of a plant and an analysis result corresponding to the analysis condition and including information indicating a flowing state of a circulation material inside the plant are associated with each other, acquiring operation data including the operation manipulated variable in an operation state of the plant and a sensor value detected by a sensor provided in the plant, and outputting reference information related to the reference data corresponding to the operation data, based on the reference data and the operation data.

[0010]

According to the above aspect, the information related to the flowing state of the material inside the plant is output with reference to the reference data stored in advance in the storage unit, so that the processing load when the information related to the flowing state of the material inside the plant is output can be reduced as compared with a case where the reference data is calculated each time the simulation is executed.

Advantageous Effects of Invention

[0011]

According to the present invention, it is possible to reduce a processing load when information related to the flowing state of a material inside a plant is output.

Brief Description of Drawings

[0012]

Fig. 1 is a schematic diagram illustrating an overall configuration of a plant according to a first embodiment.

Fig. 2 is a block diagram illustrating a functional configuration of an assistance device according to the present embodiment.

Fig. 3 is a schematic diagram illustrating an example of data content of process data according to the present embodiment.

Fig. 4 is a schematic diagram illustrating an example of data content of simulation data according to the present embodiment.

Fig. 5 is a diagram for describing an example of an estimation method of a flowing state of a circulation material based on an internal image related to an inside of a plant.

Fig. 6A is a diagram illustrating an example of a flow velocity vector of the circulation material based on a mathematical model.

Fig. 6B is a diagram illustrating an example of a flow direction of the circulation material based on the internal image related to the inside of the plant.

Fig. 6C is a diagram in which the flow velocity vector

of the circulation material based on the mathematical model illustrated in Fig. 6A and a flow velocity vector of the circulation material based on the internal image related to the inside of the plant illustrated in Fig. 6B are displayed in an overlapping manner.

Fig. 7 is a flowchart illustrating processing content of update processing of the mathematical model.

Fig. 8 is a flowchart illustrating processing content of display processing of the simulation data.

Fig. 9A is a diagram for describing an operation of the assistance device according to the present embodiment.

Fig. 9B is a diagram for describing an operation of the assistance device according to the present embodiment.

Fig. 10 is a diagram for describing an estimation method of a flowing state of a circulation material by an assistance device according to a second embodiment.

Fig. 11 is a schematic diagram illustrating an example of data content of process data according to the present embodiment.

Fig. 12 is a schematic diagram illustrating an example of data content of simulation data according to the present embodiment.

Description of Embodiments

[0013]

[First Embodiment]

Hereinafter, the present invention will be described through an embodiment of the invention with reference to the drawings. It should be noted that the following embodiment does not limit the invention according to the claims. In addition, not all combinations of features described in the embodiment are essential to the solution of the invention. The same or equivalent components, members, and processing illustrated in each drawing will be designated by the same reference signs, and description will not be repeated as appropriate.

[0014]

Fig. 1 is a schematic diagram illustrating an overall configuration of a plant according to a first embodiment of the present invention. First, a configuration of a plant 1 targeted by the present embodiment will be described using Fig. 1. The plant 1 is, for example, a power generation plant (incineration plant) including a circulating fluidized bed boiler, and includes a boiler that circulates a circulation material such as silica sand that is fluidized at a high temperature while a fuel is burned and generates vapor. Not only fossil fuel, such as coal, but also, for example, non-fossil fuel (woody biomass, waste tires, waste plastic, sludge, or the like) can be used as the fuel of the plant 1. The vapor generated in the plant 1

is used for driving a turbine 100. In addition, the plant targeted by the present invention is not limited to a power generation plant or an incineration plant including a boiler, and may be any plant such as a chemical plant or a wastewater treatment plant in which process data can be acquired.

[0015]

The plant 1 is configured such that the fuel is burned in a furnace 2, a cyclone 3 which functions as a solid-gas separation device separates a circulation material from exhaust gas, and the separated circulation material is fed back to the furnace 2 and is circulated. The separated circulation material is sent back to a lower part of the furnace 2 via a circulation material recovery pipe 4 that is connected to a part below the cyclone 3. In addition, a lower part of the circulation material recovery pipe 4 and the lower part of the furnace 2 are connected through a loop seal part 4a in which a flow path is narrowed. Therefore, a predetermined amount of circulation material is stored in the lower part of the circulation material recovery pipe 4. The exhaust gas from which the circulation material has been removed by the cyclone 3 is supplied to a rear flue 5 via an exhaust gas flow path 3a.

[0016]

The boiler includes the furnace 2 for burning the fuel

and a heat exchanger for generating water vapor or the like using heat obtained by the burning. A fuel feed port 2a through which the fuel is supplied is provided in a middle part of the furnace 2, and a gas outlet 2b through which combustion gas is exhausted is provided in an upper part of the furnace 2. The fuel that is supplied to the furnace 2 from a fuel supply device (not illustrated) is supplied to the inside of the furnace 2 through the fuel feed port 2a. In addition, a furnace wall pipe 6 for heating boiler feedwater is provided in a furnace wall of the furnace 2. The boiler feedwater that flows through the furnace wall pipe 6 is heated by combustion in the furnace 2.

[0017]

In the furnace 2, a solid matter including the fuel supplied from the fuel feed port 2a is fluidized by air for combustion and fluidization introduced from an air supply line 2c provided in the lower part, and the fuel is burned at, for example, approximately 800°C to 900°C while being fluidized. The combustion gas generated in the furnace 2 is introduced into the cyclone 3 with the circulation material. The cyclone 3 separates the circulation material and gas from each other based on a centrifugal effect, feeds the separated circulation material back to the furnace 2 through the circulation material recovery pipe 4, and sends the combustion gas, from which the circulation

material has been removed, from the exhaust gas flow path 3a to the rear flue 5.

[0018]

In the furnace 2, a part of the circulation material called an in-furnace bed material remains in a bottom part. The bed material may include a bed material or an exhaust impurity having a coarse particle size that is not suitable for circulation and fluidization, and these bed materials that are not suitable as the circulation material may cause a fluidization failure. Thus, in order to suppress the fluidization failure, the in-furnace bed material is continuously or intermittently exhausted to the outside from an exhaust port 2d provided in the bottom part in the furnace 2. Metal or an unsuitable material having a coarse large particle size or the like in a circulation line (not illustrated) is removed from the exhausted bed material, and then the exhausted bed material is supplied to the furnace 2 again or is discarded. The circulation material in the furnace 2 circulates in a circulation system configured by the furnace 2, the cyclone 3, and the circulation material recovery pipe 4.

[0019]

The rear flue 5 includes a flow path through which the gas exhausted from the cyclone 3 flows to a rear stage. The rear flue 5 includes, as an exhaust heat recovery portion

that collects heat of the exhaust gas, a superheater 10 that generates superheated vapor and a coal economizer 12 that preheats the boiler feedwater. The exhaust gas flowing through the rear flue 5 is cooled by exchanging heat with the vapor or the boiler feedwater flowing through the superheater 10 and the coal economizer 12. In addition, a steam drum 8 in which the boiler feedwater that has passed through the coal economizer 12 is stored is provided, and the steam drum 8 is also connected to the furnace wall 6.

[0020]

The coal economizer 12 transfers the heat of the exhaust gas to the boiler feedwater to preheat the boiler feedwater. The coal economizer 12 is connected to a pump 7 by a pipe 21 and is connected to the steam drum 8 by a pipe 22. The boiler feedwater that has been supplied to the coal economizer 12 from the pump 7 via the pipe 21 and then preheated by the coal economizer 12 is supplied to the steam drum 8 via the pipe 22.

[0021]

A downcast pipe 8a and the furnace wall pipe 6 are connected to the steam drum 8. The boiler feedwater in the steam drum 8 moves down through the downcast pipe 8a to be introduced into the furnace wall pipe 6 on the lower side of the furnace 2 and flow toward the steam drum 8. The boiler feedwater in the furnace wall pipe 6 is heated by

combustion heat generated in the furnace 2 and evaporates into vapor in the steam drum 8.

[0022]

A saturated vapor pipe 8b through which the vapor inside the steam drum 8 is exhausted is connected to the steam drum 8. The saturated vapor pipe 8b connects the steam drum 8 and the superheater 10. The vapor in the steam drum 8 is supplied to the superheater 10 via the saturated vapor pipe 8b. The superheater 10 superheats the vapor by using the heat of the exhaust gas to generate the superheated vapor. The superheated vapor is supplied to the turbine 100 outside the plant 1 through a pipe 10a and is used for power generation.

[0023]

The pressure and temperature of the vapor exhausted from the turbine 100 are lower than the pressure and temperature of the vapor exhausted from the superheater 10. Although not particularly limited, the pressure of the vapor supplied to the turbine 100 is approximately 10 to 17 MPa, and the temperature of the vapor is approximately 530°C to 570°C. The pressure of the vapor exhausted from the turbine 100 is approximately 3 to 5 MPa, and the temperature of the vapor is approximately 350°C to 400°C.

[0024]

A condenser 102 is provided on a downstream side of

the turbine 100. The vapor exhausted from the turbine 100 is supplied to the condenser 102, condensed in the condenser 102, returned into saturated water, and then supplied to the pump 7. A generator that converts kinetic energy obtained by rotation of the turbine 100 into electrical energy is connected to the turbine 100.

[0025]

A pump 7a supplies makeup water to constantly maintain a water level of the condenser 102. In Fig. 1, a makeup water flow rate u_1 supplied by the pump 7a is illustrated.

[0026]

The process data to be handled in the present embodiment may be any data related to the plant 1, but may be, for example, data obtained by measuring a state of the plant 1 with a sensor, and more specifically, may include measurement values of a temperature, a pressure, a flow rate, or the like of the plant 1. In Fig. 1, a boiler feedwater flow rate u_2 supplied from the pump 7 to the coal economizer 12 is illustrated. Further, in Fig. 1, a boiler outlet vapor flow rate u_3 supplied from the superheater 10 to the turbine 100 is illustrated, and a saturated vapor flow rate u_4 supplied from the steam drum 8 to the superheater 10 is illustrated. Furthermore, the makeup water flow rate u_1 may be controlled to follow the saturated vapor flow rate u_4 . In addition, the boiler

feedwater flow rate u_2 may be controlled to follow adjustment while both the boiler outlet vapor flow rate u_3 (or a superheated vapor flow rate) and the liquid level of the steam drum 8 are monitored.

[0027]

When a hole is generated in the plant 1, the makeup water flow rate u_1 increases, or the flow rate difference between the boiler feedwater flow rate u_2 and the boiler outlet vapor flow rate u_3 increases. A distributed control system (DCS) 20 monitors whether or not there is an abnormality in the process data of the plant 1 such as the makeup water flow rate u_1 , the boiler feedwater flow rate u_2 , the boiler outlet vapor flow rate u_3 , and the saturated vapor flow rate u_4 .

[0028]

In addition, the makeup water flow rate u_1 , the boiler feedwater flow rate u_2 , the boiler outlet vapor flow rate u_3 , and the saturated vapor flow rate u_4 are given as examples of the process data, but the process data related to the plant 1 may be other data. The process data related to the plant 1 may be other data such as a temperature and a pressure.

[0029]

Fig. 2 is a block diagram illustrating a control configuration of an assistance device 200 according to the

present embodiment.

[0030]

As illustrated in Fig. 2, the assistance device 200 is a device that assists the operation of the plant 1, and for example, by inputting an analysis condition including an operation manipulated variable of the plant 1 to a mathematical model 224, outputs information indicating the flowing state of the circulation material inside of the plant 1 included in an analysis result corresponding to the analysis condition, from the mathematical model 224. The operation manipulated variable of the plant 1 includes, for example, a temperature, a pressure, and a flow rate of the plant 1. The mathematical model 224 is a model for simulating and reproducing the flowing state of the circulation material inside the plant 1 under a predetermined analysis condition. Then, the assistance device 200 generates an image indicating the flowing state of the circulation material, based on the information output from the mathematical model 224, and displays the generated image.

[0031]

For example, the assistance device 200 includes a control unit 210 and a storage unit 220.

The control unit 210 is realized, for example, when a hardware processor such as a central processing unit (CPU)

executes a program (software). In addition, some or all of the components may be realized by hardware (a circuit unit including a circuitry) such as a large scale integration (LSI), an application specific integrated circuit (ASIC), a field-programmable gate array (FPGA), and a graphics processing unit (GPU), or may be realized by the cooperative operation of software and hardware. The program may be stored in advance in a computer-readable recording device, such as an HDD or a flash memory, of the assistance device 200, or may be stored in a detachable computer-readable recording medium, such as a DVD or a CD-ROM and installed in the HDD or the flash memory of the assistance device 200 when the computer-readable recording medium is installed in the drive device.

[0032]

For example, the assistance device 200 is connected to the distributed control system (DCS) 20, an input device 110, and a display device 120.

[0033]

The DCS 20 acquires the data detected by the sensor installed inside the plant 1 during the operation of the plant 1 as the process data 222 during the operation of the plant 1 and outputs the data to the assistance device 200. The process data 222 is an example of operation data.

[0034]

For example, an operation for changing a parameter of the operation manipulated variable of the plant 1 is input to the input device 110. For example, the input device 110 inputs an analysis condition including the changed operation manipulated variable of the plant 1 to the mathematical model 224.

[0035]

For example, the display device 120 displays an image indicating the flowing state of the circulation material generated by the assistance device 200. For example, when an operation for changing a parameter of the operation manipulated variable of the plant 1 is input to the input device 110, the display device 120 displays an image indicating the flowing state of the circulation material obtained by inputting the analysis condition including the changed operation manipulated variable of the plant 1 to the mathematical model 224.

[0036]

For example, the control unit 210 includes a reception unit 211, an information acquisition unit 212, an image acquisition unit 213, an image processing unit 214, a simulator unit 215, a calculation unit 216, and an output unit 217.

[0037]

The reception unit 211 receives a change in the

parameter of the operation manipulated variable of the plant 1. For example, when an operation for changing the parameter of the operation manipulated variable of the plant 1 is input to the input device 110, the reception unit 211 receives the parameter of the operation manipulated variable of the plant 1 after the change from the input device 110.

[0038]

In addition, the reception unit 211 receives an input of the model parameter of the mathematical model 224. For example, when an operation for setting an initial value of the model parameter of the mathematical model 224 is input to the input device 110, the reception unit 211 receives the initial value of the model parameter from the input device 110 and applies the initial value to the mathematical model 224.

[0039]

The information acquisition unit 212 acquires operation data including the operation manipulated variable in the operation state of the plant 1 and the sensor value detected by the sensor provided in the plant 1. For example, the information acquisition unit 212 acquires the process data 222 during the operation of the plant 1 from the plant 1 via the DCS 20 and stores the process data 222 in the storage unit 220.

[0040]

Fig. 3 is a diagram illustrating an example of the data content of the process data 222. In the example illustrated in the drawing, the process data 222 associates data ID with the analysis condition and the monitor value. The analysis condition includes a plurality of operation manipulated variables of the plant 1 during the acquisition of the process data 222 targeted to be analyzed. The monitor value includes, for example, position information and sensor values. The position information is information related to a position of each of the plurality of sensors installed inside the plant 1. The sensor value is a value detected by each of the plurality of sensors and includes information related to the flowing state of the circulation material. The flowing state of the circulation material includes, for example, information related to the flow direction of the circulation material. In this example, the position information is represented by two-dimensional coordinates when the information related to the flowing state of the circulation material is visualized on the screen of the display device 120. The sensor value is information related to the flow direction of the circulation material for each position inside the plant 1, and is represented by an angle of the flow direction of the circulation material with the origin in a reference

coordinate system as the center.

[0041]

The image acquisition unit 213 acquires an internal image related to the inside of the plant 1. The image related to the inside of the plant 1 includes not only an image inside the plant 1 directly captured by a camera or the like but also an image generated based on the detection result or the like of the sensor provided inside the plant 1.

[0042]

For example, the image processing unit 214 includes a damage determination unit 214A. The damage determination unit 214A determines the damaged portion of the plant 1 by executing image processing on the internal image related to the inside of the plant 1 acquired by the image acquisition unit 213.

[0043]

For example, the simulator unit 215 includes an analysis execution unit 215A and a model updating unit 215B, inputs an analysis condition including the operation manipulated variable of the plant 1 to the mathematical model 226, and outputs information indicating the flowing state of the circulation material inside the plant 1 included in the analysis result corresponding to the analysis condition, as a simulation result.

[0044]

The analysis execution unit 215A inputs an analysis condition including the operation manipulated variable of the plant 1 to the mathematical model 224 and analyzes information indicating the flowing state of the circulation material inside the plant 1 included in the analysis result corresponding to the analysis condition. The analysis execution unit 215A stores simulation data 223 in which the analysis condition including the operation manipulated variable of the plant 1 is associated with the analysis result corresponding to the analysis condition, in the storage unit 220. The simulation data 223 is an example of reference data. For example, the analysis execution unit 215A stores the simulation data 223 in which a plurality of analysis conditions are associated with the analysis result corresponding to each of the plurality of analysis conditions, in the storage unit 220. When the reception unit 211 described above receives a change in the parameter of the operation manipulated variable of the plant 1, the analysis execution unit 215A analyzes information indicating the flowing state of the circulation material inside the plant 1 corresponding to the changed parameter.

[0045]

Fig. 4 is a diagram illustrating an example of the data content of the simulation data 223. In the example

illustrated in the drawing, the simulation data 223 associates the data ID with the input data and the output data. The input data is data input to the mathematical model 224, and includes the plurality of analysis conditions during the analysis of the simulation data 223. The output data is data output from the mathematical model 224, and includes, for example, position information and monitor points. The position information includes information indicating a part of the plant 1. The monitor point is information analyzed by the mathematical model 224 for each part of the plant 1, and includes information related to the flowing state of the circulation material. In this example, the position information is represented by two-dimensional coordinates when the information related to the flowing state of the circulation material is visualized on the screen of the display device 120. The sensor value is information related to the flow direction of the circulation material for each position inside the plant 1, and is represented by an angle of the flow direction of the circulation material with the origin in a reference coordinate system as the center.

[0046]

The model updating unit 215B updates the mathematical model 224, based on the flowing state of the circulation material inside the plant 1 estimated based on the internal

image related to the inside of the plant 1 acquired by the image acquisition unit 213, and information indicating the flowing state of the circulation material included in the analysis result of the simulation data 223 stored in the storage unit 220. The estimation of the flowing state of the circulation material inside the plant 1 based on the internal image of the plant 1 is performed, for example, manually by an operator of the plant 1. For example, the operator of the plant 1 visually confirms a direction in which the damaged portion of the plant 1 extends, based on the internal image of the plant 1, and estimates the flow direction of the circulation material based on the direction in which the damaged portion of the plant 1 extends.

[0047]

Fig. 5 is a diagram for describing an example of the estimation method of the flowing state of the circulation material based on the internal image related to the inside of the plant 1. In the example illustrated in the drawing, the damage determination unit 214A determines the damaged portion of the plant 1 in advance, based on the internal image of the plant 1. In this case, since it is assumed that the inner wall of the plant 1 is damaged by the circulation material inside the plant 1, it is considered that the direction in which the damaged portion of the

plant 1 extends and the flow direction of the circulation material inside the plant 1 substantially coincide with each other. Therefore, the operator of the plant 1 visually confirms that the direction in which the damaged portion of the plant 1 extends is a direction along the up-down direction, based on the internal image of the plant 1. Then, the operator of the plant 1 estimates a direction (in this example, an upward direction) from one side to the other side along the direction in which the damaged portion of the plant 1 extends, as the flow direction of the circulation material inside the plant 1. In this case, for example, the operator of the plant 1 compares the direction in which the damaged portion of the plant 1 extends with the direction of the flow velocity vector corresponding to the damaged portion of the plant 1, which is analyzed based on the mathematical model 224, and estimates the direction relatively close to the direction of the flow velocity vector, among two directions along the direction in which the damaged portion of the plant 1 extends, as the flow direction of the circulation material inside the plant 1.

[0048]

Fig. 6A is a diagram illustrating an example of a flow velocity vector of the circulation material based on the mathematical model 224. In this example, information indicating the flowing state of the circulation material

inside the plant 1 included in the analysis result of the mathematical model 224 is visualized and displayed. The information indicating the flowing state of the circulation material includes the flow direction of the circulation material for each part of the plant 1. In the example illustrated in Fig. 6A, the direction of an arrow in the diagram indicates the flow direction of the circulation material, and the length of the arrow in the diagram indicates the flow speed of the circulation material. This aspect of the arrow is the same in other drawings.

[0049]

Fig. 6B is a diagram illustrating an example of the flow direction of the circulation material based on the internal image related to the inside of the plant 1. In this example, the flow direction of the circulation material inside the plant 1 is visualized and displayed for each part of the plant 1.

[0050]

Fig. 6C is a diagram in which the flow velocity vector of the circulation material based on the mathematical model 224 illustrated in Fig. 6A and the flow velocity vector of the circulation material based on the internal image related to the inside of the plant 1 illustrated in Fig. 6B are displayed in an overlapping manner. As illustrated in the drawing, there is a slight deviation between the flow

velocity vector of the circulation material based on the mathematical model 224 and the flow velocity vector of the circulation material based on the internal image related to the inside of the plant 1. Therefore, the model updating unit 215B updates the model parameter of the mathematical model 224 to reduce the deviation. Specifically, the model updating unit 215B sets an evaluation function illustrated in the following Expression 1 to search for an optimal value S of the model parameter.

[Expression 1]

$$S(Model) = \sum_i \mathbf{U}_i - \mathbf{V}_i$$

[0051]

In addition, the model updating unit 215B may set weighting for each flow velocity vector and set the evaluation function illustrated in Expression 2.

[Expression 2]

$$S(Model) = \sum_i \alpha_i (\mathbf{U}_i - \mathbf{V}_i)$$

[0052]

In addition, the model updating unit 215B may set an evaluation function illustrated in Expression 3 to reduce the inner product between the unit vectors of each flow velocity vector.

[Expression 3]

$$S(Model) = \sum_i 1 - \left(\frac{U_i}{|U_i|} \cdot \frac{V_i}{|V_i|} \right)^2$$

[0053]

The calculation unit 216 calculates a similarity between the simulation data 223 stored in the storage unit 220 and the process data 222 acquired by the information acquisition unit 212. For example, the calculation unit 216 calculates the similarity between the simulation data 223 and the process data 222 based on the similarity between the plurality of operation manipulated variables included in the process data 222 and the analysis conditions included in the simulation data 223, the analysis condition corresponding to each of the plurality of operation manipulated variables, and the similarity between a plurality of sensor values included in the process data 222 and the monitor points included in the simulation data 223, the monitor point corresponding to each of the plurality of sensor values. For example, the calculation unit 216 calculates the similarity described above as a Euclidean distance based on the following Expression 4 when the plurality of operation manipulated variables and the plurality of sensor values are defined as p_n and the analysis condition corresponding to each of the plurality of operation manipulated variables and the monitor point corresponding to each of the plurality of sensor values are

defined as q_n .

[Expression 4]

$$d(\mathbf{p}, \mathbf{q}) = d(\mathbf{q}, \mathbf{p}) = \sqrt{(q_1 - p_1)^2 + (q_2 - p_2)^2 + \cdots + (q_n - p_n)^2} = \sqrt{\sum_{i=1}^n (q_i - p_i)^2}$$

[0054]

The output unit 217 outputs the analysis condition included in the simulation data 223 corresponding to the process data 222 and information related to the monitor point associated with the position information as an example of reference information, based on the simulation data 223 and the process data 222. For example, the output unit 217 outputs the reference information based on the similarity between the simulation data 223 calculated by the calculation unit 216 and the process data 222. The output unit 217 outputs the reference information having the maximum similarity to the process data 222, which is calculated by the calculation unit 216, from the simulation data 223 stored in the storage unit 220. For example, the output unit 217, for each data ID included in the simulation data 223, calculates the similarity between the plurality of operation manipulated variables and the analysis condition corresponding to each of the plurality of operation manipulated variables, and calculates the similarity between the plurality of sensor values and the monitor point corresponding to each of the plurality of

sensor values. Then, the output unit 217 determines the data ID for which the similarity between the process data 222 and the simulation data 223 is maximized, based on the similarities, and outputs the information related to the plurality of operation manipulated variables corresponding to the determined data ID and the plurality of monitor points associated with the position information, as the reference information.

[0055]

Next, the update processing of the mathematical model 224 executed by the assistance device 200 according to the present embodiment will be described with reference to a flowchart illustrated in Fig. 7. The flowchart illustrated in Fig. 7 is repeatedly executed at a predetermined cycle, for example.

[0056]

As illustrated in Fig. 7, as the estimation processing based on the internal image, the image acquisition unit 213 first acquires the internal image related to the inside of the plant 1 (step S10).

[0057]

Next, the damage determination unit 214A determines the damaged portion of the plant 1 from the internal image by executing image processing on the internal image acquired in the previous step S10 (step S11). Based on the

damaged portion of the plant 1, which is determined as the above, the flowing state of the circulation material is manually estimated by the operator of the plant 1, and the estimation processing based on the internal image is ended.

[0058]

Next, as the analysis processing based on the mathematical model 224, the model updating unit 215B applies the initial value of the model parameter received by the reception unit 211 to the mathematical model 224 and sets the mathematical model 224 (step S12).

[0059]

Next, the analysis execution unit 215A analyzes the flowing state of the circulation material inside the plant 1 by inputting the analysis condition received by the reception unit 211 to the mathematical model 224 (step S13).

[0060]

Then, the analysis execution unit 215A outputs the analysis result related to the flowing state of the circulation material analyzed in the previous step S13 (step S14), and the analysis processing based on the mathematical model 224 is ended.

[0061]

Next, the model updating unit 215B evaluates the mathematical model 224 based on a comparison between the

flowing state of the circulation material estimated by the estimation processing based on the internal image described above and the flowing state of the circulation material analyzed by the analysis processing based on the mathematical model 224 described above (step S15).

[0062]

Then, when the evaluation result of the mathematical model 224 in the previous step S15 does not satisfy a predetermined condition (step S16 = NO), the model updating unit 215B optimizes the model parameter of the mathematical model 224 (step S17), then returns the processing to the step S12, and repeats the processing of the step S12 to the step S17 until the evaluation result of the mathematical model 224 satisfies the predetermined condition.

[0063]

On the other hand, when the evaluation result of the mathematical model 224 in the previous step S16 satisfies the predetermined condition (step S16 = YES), the model updating unit 215B ends the update processing of the mathematical model 224 illustrated in Fig. 7.

[0064]

Next, the display processing of the simulation data executed by the assistance device 200 according to the present embodiment will be described with reference to a flowchart illustrated in Fig. 8. The flowchart illustrated

in Fig. 8 is started, for example, when an input command from an operator of the plant 1 is received.

[0065]

As illustrated in Fig. 8, the information acquisition unit 212 first acquires the process data 222 from the plant 1 via the DCS 20 (step S20).

[0066]

Next, the calculation unit 216 evaluates the similarity between the process data 222 acquired in the previous step S20 and the simulation data 223 stored in the storage unit 220 (step S21).

[0067]

Next, the output unit 217 selects the simulation data 223 evaluated to have the highest similarity to the process data 222 in the previous step S21, from the simulation data 223 stored in the storage unit 220 (step S22).

[0068]

Next, the output unit 217 outputs the simulation data 223 selected in the previous step S22 to the display device 120 to display the simulation data 223 (step S23).

[0069]

Next, the output unit 217 determines whether or not the reception unit 211 has received an operation of changing the analysis condition of the simulation data 223 (step S24). When the output unit 217 determines that the

reception unit 211 has received the operation of changing the analysis condition of the simulation data 223 (step S24 = YES), the output unit 217 selects the simulation data 223 corresponding to the analysis condition after the change from the simulation data 223 stored in the storage unit 220 (step S25).

[0070]

Next, the output unit 217 outputs the simulation data 223 selected in the previous step S25 to the display device 120 to display the simulation data 223 (step S26).

[0071]

Next, the output unit 217 determines whether or not the display of the simulation data 223 is ended, based on the input operation from the input device 110 (step S27). When the output unit 217 determines that the display of the simulation data 223 is not ended (step S27 = NO), the output unit 217 returns the processing to the step S24, and repeats the processing from the step S24 to the step S27 until the output unit 217 determines that the display of the simulation data is ended. On the other hand, when the output unit 217 determines that the display of the simulation data 223 is to be ended (step S27 = YES), the output unit 217 ends the display processing of the simulation data 223 illustrated in Fig. 8.

[0072]

In addition, in the previous step S24, when the output unit 217 determines that the reception unit 211 has not received the operation of changing the analysis condition of the simulation data 223 (step S24 = NO), the output unit 217 ends the display processing of the simulation data 223 illustrated in Fig. 8 without performing the processing of the step S25 to the step S27.

[0073]

Next, an operation of the assistance device 200 according to the present embodiment will be described.

[0074]

As illustrated in Fig. 9A, when the assistance device 200 executes the simulation related to the flowing state of the circulation material, the assistance device 200 first compares the process data 222 indicating the current operation state of the plant 1 with the simulation data 223 corresponding to the plurality of analysis conditions stored in the storage unit 220. In addition, the assistance device 200 selects the simulation data 223 having the highest similarity to the process data 222, and displays the analysis condition corresponding to the selected simulation data 223 on the display device 120. Then, when an icon IA of the display device 120 is operated by the operator of the plant 1, the assistance device 200 starts executing the simulation. In this case, as illustrated in

Fig. 9B, the assistance device 200 displays a simulation image GB illustrating the flowing state of the circulation material under the analysis condition described above on the display device 120. In addition, the assistance device 200 displays the internal image GA related to the inside of the plant 1 corresponding to each position of the plant 1 in association with the simulation image GB indicating the flowing state of the circulation material. That is, the assistance device 200 outputs the internal image GA acquired by the image acquisition unit 213 in association with information indicating a part of the plant 1. In addition, the assistance device 200 superimposes an image GC indicating the flow direction of the circulation material estimated based on the internal image GA related to the inside of the plant 1 on the simulation image GB indicating the flowing state of the circulation material in a position corresponding to the internal image GA related to the inside of the plant 1. That is, the internal flow information including the flow direction of the circulation material estimated based on the internal image GA acquired by the image acquisition unit 213 is output in further association with the information indicating a part of the plant 1. Then, in addition to the simulation image GB indicating the flowing state of the circulation material, the internal image GA related to the inside of the plant 1

and the image GC indicating the flow direction of the circulation material estimated based on the internal image GA are displayed in a superimposed manner in a state of being associated with the simulation image GB, so that information related to the flowing state of the circulation material can be more accurately identified.

[0075]

In addition, as illustrated in Fig. 9A, the assistance device 200 receives a change in the analysis condition of the simulation data, and, when a part of the parameter is changed, refers to the analysis condition of the simulation data stored in the storage unit 220 to search for the analysis condition corresponding to the changed parameter. Then, the assistance device 200 displays the simulation image GB indicating the flowing state of the circulation material under the searched analysis condition on the display device 120.

[0076]

[Second Embodiment]

In the following second embodiment and later, the description of the matters common to the first embodiment will be omitted, and only the different points will be described. In particular, the same operation and effects due to the same configuration will not be repeatedly described for each embodiment.

[0077]

As illustrated in Fig. 10, Fig. 10 is a diagram for describing an example of the estimation method of the flowing state of the circulation material based on an internal image GA related to the inside of the plant 1 in the assistance device 200 according to the present embodiment. In the example illustrated in the drawing, the operator of the plant 1 analyzes the time-dependent change of the damaged portion of the plant 1 determined in advance with respect to the plurality of internal images GA captured at different time points. In this manner, in addition to the direction in which the damaged portion of the plant 1 extends, the extension amount of the damaged portion of the plant 1 is identified over a predetermined period, and the flow speed of the circulation material can be estimated in addition to the flow direction of the circulation material.

[0078]

Fig. 11 is a diagram illustrating an example of the data content of process data 222A. In the example illustrated in the drawing, the process data 222A associates the data ID with the analysis condition and the monitor value. The analysis condition includes a plurality of operation manipulated variables of the plant 1 during the acquisition of the process data 222A targeted to be

analyzed. The monitor value includes, for example, position information and sensor values. The position information is information related to a position of each of the plurality of sensors installed inside the plant 1. The sensor value is a value detected by each of the plurality of sensors and includes information related to the flowing state of the circulation material. The flowing state of the circulation material includes, for example, a flow direction of the circulation material and a flow speed of the circulation material. In this example, the position information is represented by two-dimensional coordinates when the information related to the flowing state of the circulation material is visualized on the screen of the display device 120. The sensor value is information related to the flow direction and the flow speed of the circulation material for each position inside the plant 1. The flow direction of the circulation material is represented by an angle of the flow direction of the circulation material with the origin in the reference coordinate system as the center. The flow speed of the circulation material indicates the flow speed of the circulation material with a position inside the plant 1 indicated by the position information as a starting point.

[0079]

Fig. 12 is a diagram illustrating an example of the

data content of the simulation data 223A. In the example illustrated in the drawing, the simulation data 223A associates the data ID with the input data and the output data. The input data is data input to the mathematical model 224, and includes the plurality of analysis conditions during the analysis of the simulation data 223A. The output data is data output from the mathematical model 224, and includes, for example, position information and monitor points. The position information includes information indicating a part of the plant 1. The monitor point is information analyzed by the mathematical model 224 for each part of the plant 1, and includes information related to the flowing state of the circulation material. The flowing state of the circulation material includes, for example, a flow direction of the circulation material and a flow speed of the circulation material. In this example, the position information is represented by two-dimensional coordinates when the information related to the flowing state of the circulation material is visualized on the screen of the display device 120. The sensor value is information related to the flow direction and the flow speed of the circulation material for each position inside the plant 1, and the flow direction of the circulation material is represented by an angle of the flow direction of the circulation material with the origin in the

reference coordinate system as the center. The flow speed of the circulation material indicates the flow speed of the circulation material with a position inside the plant 1 indicated by the position information as a starting point.

[0080]

The model updating unit 215B updates the mathematical model 224, based on the flowing state of the circulation material inside the plant 1 estimated based on the internal image related to the inside of the plant 1 acquired by the image acquisition unit 213, and information indicating the flowing state of the circulation material included in the analysis result of the simulation data 223A stored in the storage unit 220. For example, the operator of the plant 1 evaluates the similarity between the flow direction of the circulation material estimated based on the internal image and the flow direction of the circulation material included in the analysis result of the simulation data 223A. In addition, the operator of the plant 1 evaluates the similarity between the flow speed of the circulation material estimated based on the internal image and the flow speed of the circulation material included in the analysis result of the simulation data 223A. Then, the operator of the plant 1 evaluates the degree of deviation between the flowing state of the circulation material included in the analysis result of the simulation data 223A and the actual

flowing state of the circulation material, based on the evaluation result of the similarity, and updates the model parameter of the mathematical model 224 such that the degree of deviation decreases.

[0081]

[Appendix]

The technical idea that can be identified from each of the embodiments described above will be described below.

(Appendix 1)

An assistance device to assist an operation of a plant, the assistance device including:

a storage unit that stores reference data in which an analysis condition including an operation manipulated variable of the plant and an analysis result corresponding to the analysis condition are associated with each other, the analysis result including information indicating a flowing state of a circulation material inside the plant;

an information acquisition unit that acquires operation data including the operation manipulated variable in an operation state of the plant and a sensor value detected by a sensor provided in the plant; and

an output unit that outputs reference information related to the reference data corresponding to the operation data, based on the reference data and the operation data.

(Appendix 2)

The assistance device according to Appendix 1, further including:

a calculation unit that calculates a similarity between the reference data and the operation data, in which the output unit outputs the reference information based on the similarity calculated by the calculation unit.

(Appendix 3)

The assistance device according to Appendix 2, in which

the output unit outputs the reference information in which the similarity calculated by the calculation unit is a maximum, from the reference data stored in the storage unit.

(Appendix 4)

The assistance device according to Appendix 2 or 3, in which

the calculation unit calculates the similarity based on respective similarities between the reference data and each of the operation manipulated variable and the sensor value included in the operation data.

(Appendix 5)

The assistance device according to any one of Appendices 1 to 4, further including:

an image acquisition unit that acquires an internal

image related to an inside of the plant, in which

the reference data includes information indicating a part of the plant, and

the output unit outputs the internal image in association with the information indicating the part of the plant.

(Appendix 6)

The assistance device according to Appendix 5, in which

the output unit outputs internal flow information including a flow direction of the circulation material estimated based on the internal image further in association with the information indicating the part of the plant.

(Appendix 7)

The assistance device according to any one of Appendices 1 to 6, further including:

a simulator unit that inputs the analysis condition including the operation manipulated variable of the plant to a mathematical model and outputs the information indicating the flowing state of the circulation material inside the plant included in the analysis result corresponding to the analysis condition as a simulation result.

(Appendix 8)

The assistance device according to Appendix 7, in which

the simulator unit further includes a model updating unit that updates the mathematical model based on the flowing state of the circulation material inside the plant estimated based on an internal image related to an inside of the plant and the information indicating the flowing state of the circulation material included in the analysis result of the reference data.

(Appendix 9)

The assistance device according to any one of Appendices 1 to 8, further including:

a reception unit that receives a change in a parameter of the operation manipulated variable of the plant, in which

the simulator unit outputs an analysis result corresponding to the changed parameter.

(Appendix 10)

An assistance method for assisting an operation of a plant, the method including:

storing reference data in which an analysis condition including an operation manipulated variable of the plant and an analysis result corresponding to the analysis condition and including information indicating a flowing state of a circulation material inside the plant are

associated with each other;

acquiring operation data including the operation manipulated variable in an operation state of the plant and a sensor value detected by a sensor provided in the plant; and

outputting reference information related to the reference data corresponding to the operation data, based on the reference data and the operation data.

(Appendix 11)

A program causing a computer to execute a process including:

storing reference data in which an analysis condition including an operation manipulated variable of a plant and an analysis result corresponding to the analysis condition and including information indicating a flowing state of a circulation material inside the plant are associated with each other;

acquiring operation data including the operation manipulated variable in an operation state of the plant and a sensor value detected by a sensor provided in the plant; and

outputting reference information related to the reference data corresponding to the operation data, based on the reference data and the operation data.

[0082]

Each embodiment described above is for facilitating the understanding of the present invention, and is not for limiting and interpreting the present invention. The present invention can be changed or improved without departing from the concept of the present invention, and the present invention also includes equivalents thereof. That is, even those to which the person skilled in the art has appropriately made a design change in each embodiment are included in the scope of the present invention as long as the features of the present invention are provided. For example, each element included in each embodiment, and a disposition, a material, a condition, a shape, a size, or the like thereof can be appropriately changed without being limited to the examples. In addition, each embodiment is an example, and it goes without saying that partial substitution or combination of the configurations illustrated in different embodiments is possible, and is also included in the scope of the present invention as long as the partial substitution or combination includes the features of the present invention.

Reference Signs List

[0083]

1 Plant

20 DCS

- 110 Input device
- 120 Display device
- 200 Assistance device
- 210 Control unit
 - 211 Reception unit
 - 212 Information acquisition unit
 - 213 Image acquisition unit
 - 214 Image processing unit
 - 214A Damage determination unit
 - 215 Simulator unit
 - 215A Analysis execution unit
 - 215B Model updating unit
 - 216 Calculation unit
 - 217 Output unit
- 220 Storage unit
 - 221 Image data
 - 222 Process data
 - 223 Simulation data
 - 224 Mathematical model

CLAIMS

1. An assistance device to assist an operation of a plant, the assistance device comprising:

a storage unit that stores reference data in which an analysis condition including an operation manipulated variable of the plant and an analysis result corresponding to the analysis condition are associated with each other, the analysis result including information indicating a flowing state of a circulation material inside the plant;

an information acquisition unit that acquires operation data including the operation manipulated variable in an operation state of the plant and a sensor value detected by a sensor provided in the plant; and

an output unit that outputs reference information related to the reference data corresponding to the operation data, based on the reference data and the operation data.

2. The assistance device according to claim 1, further comprising:

a calculation unit that calculates a similarity between the reference data and the operation data, wherein

the output unit outputs the reference information based on the similarity calculated by the calculation unit.

3. The assistance device according to claim 2,
wherein

the output unit outputs the reference information in which the similarity calculated by the calculation unit is a maximum, from the reference data stored in the storage unit.

4. The assistance device according to claim 2,
wherein

the calculation unit calculates the similarity based on respective similarities between the reference data and each of the operation manipulated variable and the sensor value included in the operation data.

5. The assistance device according to claim 1,
further comprising:

an image acquisition unit that acquires an internal image related to an inside of the plant, wherein

the reference data includes information indicating a part of the plant, and

the output unit outputs the internal image in association with the information indicating the part of the plant.

6. The assistance device according to claim 5,
wherein

the output unit outputs internal flow information including a flow direction of the circulation material estimated based on the internal image further in association with the information indicating the part of the plant.

7. The assistance device according to claim 1,
further comprising:

a simulator unit that inputs the analysis condition including the operation manipulated variable of the plant to a mathematical model and outputs the information indicating the flowing state of the circulation material inside the plant included in the analysis result corresponding to the analysis condition as a simulation result.

8. The assistance device according to claim 7,
wherein

the simulator unit further includes a model updating unit that updates the mathematical model based on the flowing state of the circulation material inside the plant estimated based on an internal image related to an inside of the plant and the information indicating the flowing

state of the circulation material included in the analysis result of the reference data.

9. The assistance device according to claim 7, further comprising:

a reception unit that receives a change in a parameter of the operation manipulated variable of the plant, wherein the simulator unit outputs an analysis result corresponding to the changed parameter.

10. An assistance method for assisting an operation of a plant, the method comprising:

storing reference data in which an analysis condition including an operation manipulated variable of the plant and an analysis result corresponding to the analysis condition and including information indicating a flowing state of a circulation material inside the plant are associated with each other;

acquiring operation data including the operation manipulated variable in an operation state of the plant and a sensor value detected by a sensor provided in the plant; and

outputting reference information related to the reference data corresponding to the operation data, based on the reference data and the operation data.

11. A program causing a computer to execute a process comprising:

storing reference data in which an analysis condition including an operation manipulated variable of a plant and an analysis result corresponding to the analysis condition and including information indicating a flowing state of a circulation material inside the plant are associated with each other;

acquiring operation data including the operation manipulated variable in an operation state of the plant and a sensor value detected by a sensor provided in the plant; and

outputting reference information related to the reference data corresponding to the operation data, based on the reference data and the operation data.