

DESCRIPTION

Title of Invention

DISPLAY DEVICE, DISPLAY METHOD, CONTROL DEVICE, AND
COMPUTER PROGRAM

Technical Field

[0001]

The present invention relates to a display device, a display method, a control device, and a computer program.

Background Art

[0002]

In the related art, installing a plurality of sensors in a target object to be monitored such as a plant, monitoring an operation state of the target object to be monitored based on a state quantity acquired from each sensor, and performing a control as necessary have been performed.

[0003]

PTL 1 discloses a plant operation state diagnostic device for intuitively providing an operation state of a plant to an operator. This device diagnoses the state of the plant from three viewpoints of "operation state", "environmental conservation", and "device maintenance"

based on process data. Thus, the operator can intuitively identify the state of the plant. Fig. 3 of this literature illustrates a display screen provided by the operation state diagnostic device of a waste incineration plant, which is the target object to be monitored. On this display screen, it is shown that nine process meters showing the process data and three fuzzy meters showing a diagnosis result obtained by diagnosis using fuzzy inference based on the three viewpoints are displayed.

[0004]

PTL 2 discloses a plant control and monitoring device including a display device and a calculation processing device for quickly identifying tampering (abnormality) of a plant. This device divides alarms into a plurality of groups in accordance with a constant classification reference. Thus, in a case where an alarm is generated, it is possible to quickly identify to which group instrumentation in which abnormality has occurred belongs. Fig. 3 of this literature illustrates that alarms are displayed by dividing the plant, which is the target object to be monitored, into three tiers of a process, a series that is a collection of a plurality of processes, and a plant that is a collection of a plurality of series.

Citation List

Patent Literature

[0005]

[PTL 1] Japanese Unexamined Patent Publication No.
H8-314538

[PTL 2] Japanese Unexamined Patent Publication No.
2003-177818

Summary of Invention

Technical Problem

[0006]

However, the plant operation state diagnostic device disclosed in PTL 1 displays all process data on one screen and thus, is not suitable for the target object to be monitored for which multiple pieces of process data (for example, 100 or more types) are acquired from multiple sensors.

[0007]

The plant control and monitoring device disclosed in PTL 2 merely displays alarms in tiers. That is, since alarms are quickly identified based on a tier structure in which the plant is divided in process units, evaluation cannot be performed with respect to a plurality of evaluation elements for evaluating the operation state of the target object to be monitored such as the plant.

[0008]

Therefore, an object of the present invention is to provide a display device, a display method, a control device, and a computer program that, in the case of monitoring or the like of a target object from multiple state quantities, enable an operation state and the like of the target object to be evaluated in tiers with respect to a plurality of evaluation elements and that enable a state quantity that is an evaluation factor of a certain evaluation element to be easily specified.

Solution to Problem

[0009]

One aspect of the present disclosure provides a display device configured to display a first score indicating a state quantity of a first element belonging to a first level from a plurality of types of state quantities of a target object, a second score indicating a state quantity of a second element belonging to a second level from the state quantity of a first group that is a part of the plurality of types, and a third score indicating a state quantity of a third element belonging to the second level from the state quantity of a second group that is a part of the plurality of types.

[0010]

Here, a "score" such as the "first score" or the "second score" is not limited to a numerical value and may be information indicating a level, a stage, or a degree. The "score" includes an index.

[0011]

In addition, the display device in one aspect of the present disclosure is configured to display the first score, the second score, and the third score on the same screen.

[0012]

In addition, the display device in one aspect of the present disclosure is configured to further display a fourth score indicating a state quantity of a fourth element belonging to a third level from the state quantity of a third group that is a part of the first group.

[0013]

In addition, the display device in one aspect of the present disclosure is configured to display the second score and the fourth score on the same second screen, and make a transition from the screen displaying the first score, the second score, and the third score to the second screen.

[0014]

In addition, the display device in one aspect of the present disclosure is configured to display at least one

state quantity among the plurality of types of state quantities.

[0015]

In addition, in one aspect of the present disclosure, the target object is a plant, and the state quantity is process data.

[0016]

The present disclosure provides a display method including a step of displaying a first score indicating a state quantity of a first element belonging to a first level from a plurality of types of state quantities of a target object, a step of displaying a second score indicating a state quantity of a second element belonging to a second level from the state quantity of a first group that is a part of the plurality of types, and a step of displaying a third score indicating a state quantity of a third element belonging to the second level from the state quantity of a second group that is a part of the plurality of types.

[0017]

The present disclosure provides a control device that controls a display device to display a first score indicating a state quantity of a first element belonging to a first level from a plurality of types of state quantities of a target object on the display device, display a second

score indicating a state quantity of a second element belonging to a second level from the state quantity of a first group that is a part of the plurality of types on the display device, and display a third score indicating a state quantity of a third element belonging to the second level from the state quantity of a second group that is a part of the plurality of types on the display device.

[0018]

The present disclosure provides a computer program causing a computer to generate a control instruction to display a first score indicating a state quantity of a first element belonging to a first level from a plurality of types of state quantities of a target object on a display device, display a second score indicating a state quantity of a second element belonging to a second level from the state quantity of a first group that is a part of the plurality of types on the display device, and display a third score indicating a state quantity of a third element belonging to the second level from the state quantity of a second group that is a part of the plurality of types on the display device.

[0019]

The present disclosure provides a monitoring method that is a monitoring method of monitoring a plant based on, for example, 50 or more pieces of process data and that

uses a tier structure of an n -th level. Here, n is an integer greater than or equal to 4. This tier structure includes a first element for evaluating an operation state of the plant, a plurality of elements, including a second element affecting the first element and a third element affecting the first element, that affect the first element and that belong to a second level, a plurality of elements that affect the second element and that belong to a third level, and a plurality of elements that affect the third element and that belong to a third level. A plurality of elements in the lowest tier are monitoring items associated with the process data. The lowest tier is the n -th level or lower. For example, the number of tiers including the second element may be n , and the number of tiers including the third element may be m . Here, m is an integer satisfying $m < n$. Each element is indexed and is typically indexed as a numerical value. For indexing of a certain element, indexing is performed based on an element in a lower tier affecting the element. A method of indexing may be different for elements in the same level. For example, a method of indexing for a certain element (first method) and a method of indexing for other elements (second method) among a plurality of elements belonging to a k -th level may be different. Here, k is an integer less than or equal to n . Similarly, a method of indexing the monitoring items,

which are the plurality of elements belonging to the lowest tier, may be different. The monitoring item may be indexed based on a reference value and on a value of the process data. In a case where indexed information of a certain element is displayed, it is preferable to display indexed information of the element in the lower tier affecting the element at the same time on the same display screen.

Brief Description of Drawings

[0020]

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

Fig. 2 is a functional block diagram of an operation support system according to one embodiment.

Fig. 3 is a functional block diagram of a scoring unit of the operation support system according to one embodiment.

Figs. 4A and 4B are graphs illustrating a reference value and an abnormality degree in the operation support system according to one embodiment.

Fig. 5 is a diagram illustrating a physical configuration of the operation support system according to one embodiment.

Fig. 6 is an example of a display screen of a display device of the operation support system according to one embodiment.

Fig. 7 is an example of the display screen of the display device of the operation support system according to one embodiment.

Fig. 8 is an example of the display screen of the display device of the operation support system according to one embodiment.

Description of Embodiments

[0021]

Hereinafter, an embodiment of the present invention will be described using the drawings. The following embodiment is an illustration for describing the present invention and is not intended to limit the present invention to only the embodiment.

[0022]

The present invention is applicable to a target object for which a plurality of types of state quantities can be acquired, and particularly suitably applicable to a process for which a plurality of types of process data (an example of the "state quantity") can be acquired. A plant, for example, includes various manufacturing plants in which products are manufactured, such as a chemical product

manufacturing plant, a petrochemical product manufacturing plant, a petroleum refinery plant, a steel product manufacturing plant, a food manufacturing plant, a paper pulp product manufacturing plant, a medication manufacturing plant, an automobile manufacturing plant, a mechanical product manufacturing plant, and an electrical product manufacturing plant; a power generation plant; or a waste processing plant. Applying the present invention to such a plant enables an operation state and the like of the plant to be evaluated in tiers with respect to a plurality of evaluation elements and enables the process data that is an evaluation factor of a certain evaluation element to be easily specified, as will be described below.

[0023]

The inventors of the present application have reviewed an optimal method for monitoring the plant by acquiring, for example, 100 or more types of the process data and for performing a control as necessary. Since an operator monitors the plant and performs a control as necessary, the operator has to quickly specify a cause and take a proper measure as necessary in a case where abnormality (including tampering; the same applies below) of the plant has occurred. A method of displaying 100 or more types of the process data on the same screen as in the invention disclosed in PTL 1 is not suitable for doing so.

[0024]

Meanwhile, a method of easily specifying the process data in which an alarm is generated by grouping the process data and displaying the process data in tiers as in the invention disclosed in PTL 2 is also not suitable. Since what kind of abnormality is generated in the plant by the alarm is not perceived by simply specifying the process data in which the alarm is generated (process data that has exceeded a threshold), it is difficult to take a proper measure. In addition, in a case where alarms are generated with respect to a plurality of pieces of the process data, whether the alarms are caused by the same abnormality or caused by independent types of abnormality cannot be determined. Thus, it is difficult to take a proper measure.

[0025]

Therefore, the inventors of the present application have constructed a tiered structure for evaluating the operation state of the plant by repeating specifying of the plurality of evaluation elements for evaluating the operation state of the plant and specifying of a plurality of further different evaluation elements for evaluating each evaluation element based on professional operation knowledge or the like.

[0026]

For example, what is devised is constructing, based on the professional operation knowledge or the like, a tiered structure (hereinafter, may be referred to as a "tier structure") of setting an evaluation element "thermal state" as one of the plurality of evaluation elements for evaluating an evaluation element referred to as the operation state of the plant, setting a plurality of evaluation elements such as "exhaust gas" and "furnace" as a plurality of further different evaluation elements for evaluating the evaluation element "thermal state", setting a plurality of evaluation elements such as "pressure difference" and "temperature efficiency" as a plurality of further different evaluation elements for further evaluating the evaluation element "exhaust gas", and also setting a plurality of further different evaluation elements for evaluating each evaluation element of the plurality of evaluation elements such as "furnace", and using the tier structure for evaluating the operation state of the plant. Here, the tiered structure is constructed such that an evaluation element in the lowest tier is a monitoring item for which the process data is acquired. For example, the evaluation element in the lowest tier is a monitoring item for which the process data such as "pressure" and "temperature" is acquired.

The tier structure constructed in such a manner may have the following usefulness.

[0028]

First, a relationship between the evaluation elements can be identified. Information about what kind of plurality of evaluation elements a certain evaluation element is in a chain relationship with is information identified based on the professional operation knowledge and is information that those other than a designer of the plant or the like may not easily know. Even the operator not having such professional operation knowledge or the like can easily identify the chain relationship indicating which evaluation element is related to what kind of other evaluation elements by identifying an evaluation element in a higher tier and an evaluation element in a lower tier of the evaluation element.

[0029]

Furthermore, since the evaluation element in the lowest tier is the monitoring item for which the process data is acquired, a relationship between the process data and the evaluation element can be identified. Thus, it is easy to specify a cause when abnormality of the plant occurs.

[0030]

In addition, in a case where alarms are generated with respect to a plurality of pieces of the process data, whether the alarms are caused by the same abnormality or caused by two independent types of abnormality is easily determined. In a case where a plurality of pieces of the process data belong to a lower tier of the same evaluation element, it can be determined that these pieces of the process data cause abnormality of the same evaluation element belonging to a higher tier.

[0031]

Furthermore, the inventors of the present application have devised scoring of each evaluation element. By doing so, the operation state for each level is easily identified. For example, in the case of desiring to identify the operation state of the entire plant, the operation state of the entire plant can be easily identified by constructing the tier structure in which the "operation state of the entire plant" is an evaluation element in the highest tier (first level) and by scoring each evaluation element. For example, in a case where a score of the "operation state of the entire plant" is poor, an evaluation element in a lower tier that causes abnormality of the operation state of the entire plant is easily specified by comparing scores of a plurality of evaluation elements in the lower tier.

[0032]

Furthermore, in the tier structure, evaluation elements having approximately the same effect on evaluation elements in a higher-tier level or evaluation elements for which it is meaningful to check at the same time are set as evaluation elements in the same level. For example, the "operation state of the entire plant" is set as the evaluation element in the highest tier (first level), a plurality of evaluation elements such as "environment value" and "operation efficiency" are set as the evaluation elements in the lower tier (second level), and each evaluation element is scored. By doing so, which of "environment value" and "operation efficiency" significantly affects the score of the "operation state of the entire plant" can be easily compared.

[0033]

With such a configuration, for example, which evaluation element belonging to the lower tier affects deterioration of the score can be easily specified in a case where the score of the "operation state of the entire plant" deteriorates. Similarly, a monitoring item that causes a problem can be easily specified by repeating a transition to a further lower tier. However, the evaluation elements having approximately the same effect on the evaluation element in the higher-tier level do not

necessarily have completely the same effect. For example, comparison between evaluation elements in the same level is easily performed by weighting corresponding to a degree of effect of each evaluation element or by scoring that results in a normalized value. By performing comparison between the evaluation elements, an item to which priority is to be given to take a measure is clarified.

[0034]

The constructed tier structure may be different for each plant. By setting a different tier structure for each plant, a tier structure in which a configuration unique to the plant is taken into consideration can be set. For example, a basic tier structure may be set with respect to the same type of plant, and a final tier structure may be set for each plant by carrying out correction in which a configuration unique to each plant, an operating status of each plant, or the like is taken into consideration.

[0035]

Furthermore, it is preferable to perform scoring using a different method or logic for each evaluation element. For example, scoring may be performed such that a maximum value of scores of the plurality of evaluation elements belonging to the lower tier is used as a score of the evaluation element in the higher tier depending on a certain evaluation element. For example, in the case of a

relationship in which it can be said that the evaluation element in the higher tier is also abnormal in a case where any of the plurality of evaluation elements belonging to the lower tier is abnormal, scoring can be performed using such a method. Depending on other evaluation elements, scoring may be more generally performed in accordance with a mathematical algorithm based on the scores of the plurality of evaluation elements belonging to the lower tier. Since scoring can be performed in such a manner using an optimal method for each evaluation element, evaluation accuracy can be improved.

[0036]

The number of tier levels may be different depending on the evaluation element. For example, the number of lower-tier levels of a plurality of evaluation elements belonging to the same level may be different. Since the tier structure is formed from the higher tier toward the lower tier, the number of lower-tier levels may be different even for the evaluation elements belonging to the same level.

[0037]

In addition, the same monitoring item may be an evaluation element for evaluating a plurality of evaluation elements. For example, evaluation elements belonging to a lower tier of the plurality of evaluation elements

belonging to the same level may have a common monitoring item.

[0038]

Hereinafter, an embodiment of the present invention will be described.

[0039]

[Description of Plant]

Fig. 1 is a schematic diagram illustrating an overall configuration of a plant 1 that is an example of a target to be monitored to which the present invention is applied. For example, the plant 1 according to the present embodiment is a power generation plant including a circulating fluidized bed boiler (circulating fluidized bed type) that generates vapor by combusting fuel while circulating a circulation material such as silica sand that is fluidized at a high temperature. As the fuel of the plant 1, 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. The vapor generated in the plant 1 is used for driving a turbine 100.

[0040]

The plant 1 is configured to combust the fuel in a furnace 2, separate the circulation material from exhaust gas via a cyclone 3 that functions as a solid-gas separation device, and return the separated circulation

material to the furnace 2 to be circulated. The separated circulation material is sent back to a lower part of the furnace 2 via a circulation material recovery pipe 4 connected to a part below the cyclone 3. 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. Accordingly, the lower part of the circulation material recovery pipe 4 is in a state where a predetermined amount of the circulation material is stored. The exhaust gas in which the circulation material is removed by the cyclone 3 is supplied to a rear flue 5 via an exhaust gas flow path 3a.

[0041]

The boiler includes the furnace 2 for combusting the fuel and a heat exchanger for generating water vapor or the like using heat obtained by combustion. A fuel feed port 2a through which the fuel is supplied is provided in a middle part of the furnace 2. 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.

[0042]

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 in the lower part, and the fuel is combusted 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, returns the separated circulation material to the furnace 2 through the circulation material recovery pipe 4, and sends the combustion gas in which the circulation material is removed to the rear flue 5 from the exhaust gas flow path 3a.

[0043]

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 not suitable for circulation and fluidization. These bed materials not suitable as the circulation material may cause a fluidization failure. Thus, in order to suppress such a

fluidization failure, the in-furnace bed material is continuously or intermittently exhausted to the outside from an exhaust port 2d in the bottom part in the furnace 2. Metal or an unsuitable material having a coarse large particle size or the like is removed from the exhausted bed material on a circulation line, not illustrated. Then, the bed material is either supplied to the furnace 2 again or discarded. The circulation material of the furnace 2 circulates in a circulation system configured with the furnace 2, the cyclone 3, and the circulation material recovery pipe 4.

[0044]

The rear flue 5 has 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 collection unit 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. The steam drum 8 is also connected to the furnace wall pipe 6.

[0045]

The coal economizer 12 preheats the boiler feedwater by transferring the heat of the exhaust gas to 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 is supplied to the coal economizer 12 from the pump 7 via the pipe 21 and that is preheated by the coal economizer 12 is supplied to the steam drum 8 via the pipe 22.

[0046]

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 a lower part side of the furnace 2 and then, flows 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.

[0047]

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 to 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 generates the superheated vapor by superheating the vapor using the heat of the

exhaust gas. The superheated vapor is supplied to the turbine 100 outside the plant 1 through a pipe 10a and is used for power generation.

[0048]

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

[0049]

A condenser 102 is provided downstream of the turbine 100. The vapor exhausted from the turbine 100 is supplied to the condenser 102 to be condensed and restored into saturated water in the condenser 102 and then, is 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.

[0050]

A pump 7a supplies makeup water in order to constantly maintain a water level of the condenser 102. In Fig. 1, a

makeup water flow rate u_1 (an example of the "process data") supplied by the pump 7a is illustrated.

[0051]

The process data handled in the present embodiment may be arbitrary data related to the plant 1. For example, the process data may be data (an example of the "process data") obtained by measuring a state of the plant 1 via a sensor and, more specifically, may include a measurement value such as a temperature, a pressure, and a flow rate of the plant 1. In Fig. 1, a boiler feedwater flow rate u_2 (an example of the "process data") supplied to the coal economizer 12 from the pump 7 is illustrated. Furthermore, in Fig. 1, a boiler outlet vapor flow rate u_3 (an example of the "process data") supplied to the turbine 100 from the superheater 10 is illustrated, and a saturated vapor flow rate u_4 (an example of the "process data") supplied to the superheater 10 from the steam drum 8 is illustrated. 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 be adjusted while both of the boiler outlet vapor flow rate u_3 (or a superheated vapor flow rate) and a liquid surface level of the steam drum 8 are monitored.

[0052]

In a case where a hole has occurred in a pipe system constituting the plant 1, the makeup water flow rate u_1 rises, or a difference in flow rate between the boiler feedwater flow rate u_2 and the boiler outlet vapor flow rate u_3 is increased. A distributed control system (DCS; Fig. 2) 20 receives 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 from the plant 1 to monitor an operating status of the plant 1 and to monitor whether or not abnormality has occurred in the plant 1. As will be described later, a monitoring device 40 evaluates the process data based on an alarm determination logic set for each type of abnormality and, in a case where it is determined that abnormality has occurred, causes a display device 50 to issue an alarm.

[0053]

While 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 illustrated as the process data, 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 or data calculated based on a plurality of pieces of the process data, or may be data that is acquired from the

sensor or the like and that is not obtained by calculation processing.

[0054]

[Description of Operation Support System]

Fig. 2 is a functional block diagram of the plant 1, the DCS 20, and an operation support system 30 according to the present embodiment.

[0055]

The DCS 20 is a distributed control system for controlling the plant 1. The DCS 20 acquires the process data from the sensor or the like installed in the plant 1 and supplies a control signal for controlling the plant 1 based on the process data to the plant 1.

[0056]

The operation support system 30 includes an edge/cloud computing unit 32 that acquires the process data from the DCS 20, the monitoring device 40 that acquires the process data from the edge/cloud computing unit 32 and that monitors the plant 1 based on the process data, and the display device 50 that displays the operating status of the plant 1 for the operator. The monitoring device 40 (an example of a "control device") also functions as a control device that controls the display device 50. Specifically, the monitoring device 40 acquires the process data, acquires score values of the evaluation elements based on

the process data, and displays the score values on the display device 50.

[0057]

The edge/cloud computing unit 32 includes a plurality of edge servers that are distributedly disposed in an edge part of a network, and a cloud data server that collects the process data from the plurality of edge servers and that provides the process data to the monitoring device 40. By providing the edge/cloud computing unit 32, the process data can be suitably collected from a large-scale monitoring device or from a plurality of distributed monitoring devices. However, the operation support system 30 may not include the edge/cloud computing unit 32. In this case, the operation support system 30 acquires the process data from the DCS 20 through the network.

[0058]

The monitoring device 40 includes a score display control unit 42 and a storage unit 44.

[0059]

The score display control unit 42 includes a process data acquisition unit 42A that acquires the process data from the edge/cloud computing unit 32, a scoring unit 42B that scores each evaluation element based on the process data acquired by the process data acquisition unit 42A, and a score information display unit 42C that displays score

information acquired by the scoring unit 42B on the display device 50.

[0060]

The storage unit 44 of the monitoring device stores the above tier structure and, for each evaluation element included in the tier structure, a logic for acquiring the score based on the process data and a score history in the past (for example, one year in the past). In the present embodiment, an example of constructing the tier structure consisting of three tiers (levels) and applying the present invention will be described. The present invention is also applicable to the tier structure of four or more tiers. In addition, the score may be acquired based on a plurality of pieces of the process data, or the score may be acquired based on the scores of the plurality of evaluation elements in the lower tier. The latter corresponds to acquisition of the score of the evaluation element in the higher tier based on a plurality of pieces of the process data for acquiring the scores of the plurality of evaluation elements in the lower tier.

[0061]

Fig. 3 illustrates a functional block diagram of the scoring unit 42B.

The scoring unit 42B includes a deviation distance acquisition unit 42B1 that acquires deviation distance

information indicating a degree of deviation from a reference value based on the process data acquired by the process data acquisition unit 42A, an item-specific abnormality degree indexing unit 42B2 that evaluates and quantifies the deviation distance information acquired by the deviation distance acquisition unit 42B1 based on the professional operation knowledge, and a noise removal unit 42B3 that acquires a score for the monitoring item that is the evaluation element by removing noise from information quantified by the item-specific abnormality degree indexing unit 42B2. Furthermore, the scoring unit 42B includes a middle tier totaling unit 42B4 that scores the evaluation element in a middle tier based on scores of a plurality of monitoring items. As described above, the logic for acquiring the score based on the plurality of pieces of process data can be set with a different method depending on the evaluation element. One middle tier totaling unit 42B4 of the present embodiment, as an example, is configured to set the maximum value of the scores of the plurality of evaluation elements in the lower tier as the score of the evaluation element in the middle tier.

[0062]

Furthermore, the scoring unit 42B includes all element totaling unit 42B5 that acquires the score of the evaluation element in the higher tier using a mathematical

algorithm based on the scores of the evaluation elements in a plurality of middle tiers.

[0063]

The deviation distance acquisition unit 42B1 acquires the deviation distance information indicating the degree of deviation from the reference value. In a case where there are n types of the process data, n deviation distance acquisition units 42B1 are provided in accordance with the types of the process data. The reference value is different depending on the type of the process data. Fig. 4A is a scatter plot illustrating an example of the process data and the reference value of the process data. The drawing illustrates the reference value in a case where a horizontal axis denotes the pressure of the boiler, which is the process data, and where a vertical axis denotes the temperature, and concentric ellipses that are set to have an equal abnormality degree like a contour line and that are centered at the reference value. In this example, a distance between the reference value and each ellipse in a radial direction corresponds to a deviation distance. Similarly, each deviation distance acquisition unit 42B1 acquires the deviation distance of various types of the process data. The deviation distance can be said to be information indicating a degree of deviation from an optimal operation state. As illustrated in the drawing, it

may be configured to set a threshold in the process data and, in the case of the process data exceeding the threshold, perform indexing indicating an abnormal state via the item-specific abnormality degree indexing unit 42B2.

[0064]

The item-specific abnormality degree indexing unit 42B2 quantifies the deviation distance information. In a case where there are n types of the process data, n item-specific abnormality degree indexing units 42B2 are provided in accordance with the types of the process data. Quantification is set for each process data based on a logic such as a function set based on the professional operation knowledge. For example, even in a case where the deviation distance is long, the operation state of the plant 1 may not be significantly affected depending on the process data. Meanwhile, even in a case where the deviation distance is short, the operation state of the plant 1 may be significantly affected depending on the process data. In addition, the degree of effect may not be proportional to the deviation distance. Therefore, quantification is performed for each process data based on the professional operation knowledge.

[0065]

Fig. 4B is a graph having a horizontal axis denoting the deviation distance and a vertical axis denoting a numerical value greater than or equal to 0 and less than or equal to 1. In the present embodiment, the graph is set such that the numerical value is increased as the deviation is increased. Thus, the vertical axis may be represented as the abnormality degree. For the process data separated from the reference value in Fig. 4A, quantification is performed based on the graph of the abnormality degree corresponding to the deviation distance from the reference value (deviation distance = 0) in Fig. 4B. The reference value may be determined in advance or be correctable by a user and may be configured to be dynamically changeable based on subsequently obtained data. In the case of this process data, the degree of effect on the operation state is increased in a case where the deviation distance is increased to a predetermined degree or higher. Thus, inclination of the graph is increased in accordance with an increase in the deviation distance. The interval distance may be defined by dividing a region with not only a closed curve such as an ellipse but also an arbitrary curve or the like based on the operation knowledge. In such a manner, the logic for scoring is set based on the professional operation knowledge. Output of each item-specific abnormality degree indexing unit 42B2 is normalized to a

numerical value greater than or equal to 0 and less than or equal to 1.

[0066]

The item-specific abnormality degree setting unit 42D sets a logic for quantifying (scoring; may be referred to as "indexing") the deviation distance. The logic may be intuitively and subjectively set based on the professional operation knowledge and may be different for each process data. The logic, for example, may be determined by a function such as the graph illustrated in Fig. 4B. Furthermore, the logic may be dynamically changed by taking into consideration a time-dependent change or the like.

[0067]

The noise removal unit 42B3 removes an instantaneous value or the like generated because of noise or the like in the data quantified by the item-specific abnormality degree indexing unit 42B2. Through the above process, scoring is performed for each monitoring item, which is the evaluation element in the lowest tier. From this point, quantification in the item-specific abnormality degree setting unit 42D corresponds to scoring.

[0068]

The middle tier totaling unit 42B4 scores the evaluation element in the middle tier based on the scores of the plurality of evaluation elements. The evaluation

element in the middle tier (in a case where the evaluation element is present) is scored based on the score of the evaluation element in the further lower tier. The evaluation element in the lower tier (in a case where the evaluation element is present) is scored based on the score of the evaluation element in the further lower tier. The evaluation element in the lowest tier corresponds to the monitoring item for which the process data is acquired. Accordingly, a certain evaluation element belonging to the middle tier can be said to be acquired based on the process data of the monitoring item (an example of a "first group") belonging to the lower tier of the evaluation element in the middle tier among all process data. Other evaluation elements belonging to the same middle tier can be said to be acquired based on the process data of the monitoring item (an example of a "second group") belonging to the lower tier of the evaluation element in the middle tier among all process data. The monitoring item of the first group and the monitoring item of the second group may be completely different or may be only partially different. The case of being only partially different is a case where a certain monitoring item affects a certain evaluation element and affects other evaluation elements. Similarly, the monitoring item of a certain group and the monitoring

item of the other group may be completely different or may be only partially different.

[0069]

While an example of scoring the evaluation element in the middle tier based on the scores of two evaluation elements is illustrated in Fig. 3, the invention is not limited thereto. Scoring may be performed based on the scores of three or more evaluation elements. In a case where there are n types of the process data, m (an integer of $2 \leq m < n$) middle tier totaling units 42B4 are provided. The logic for scoring the evaluation element in the middle tier may be different for each middle tier totaling unit 42B4. For example, the middle tier totaling unit 42B4 may be configured to set the score of the maximum value among the scores of the plurality of evaluation elements belonging to the lower tier as the score of the evaluation element in the middle tier. Since there are three tiers (levels) in the present embodiment, the plurality of evaluation elements belonging to the lower tier of the middle tier are the monitoring items for which the process data is acquired.

[0070]

The all element totaling unit 42B5 scores the evaluation element in the higher tier using the maximum value or a minimum value of the scores of the evaluation

elements in the lower tier or a mathematical algorithm. The evaluation element in the higher tier is scored based on the score of the evaluation element in the lower tier. The evaluation element in the lower tier is scored based on the score of the evaluation element in the further lower tier. The evaluation element in the lowest tier corresponds to the monitoring item for which the process data is acquired. Accordingly, the evaluation element in the highest tier can be said to be acquired based on all process data belonging to the lower tier in principle.

[0071]

A totaling method setting unit 42E sets a parameter necessary for the all element totaling unit 42B5. In the all element totaling unit 42B5, while setting is not necessary in the case of scoring the evaluation element using the maximum value or the minimum value, a weighting coefficient is set in the case of, for example, more generally scoring using a linear combination (a general type of the maximum value or the minimum value). Alternatively, in the case of scoring using a mathematical algorithm, a parameter unique to the algorithm is set. The weighting coefficient and the model parameter are obtained by modeling, based on the professional operation knowledge, a logic that makes a total diagnosis based on a determination result of each evaluation element (or

monitoring item). Weighting is performed in accordance with a degree of importance of each evaluation element, and setting is performed by taking into consideration a combination of each evaluation element.

[0072]

In the case of a three-tier structure, this tier corresponds to the highest tier. Thus, the evaluation element may be referred to as a total index or the like. In addition, in the present embodiment, since further deviation from the optimal operation state occurs as the score is increased, the score may be referred to as the abnormality degree or a total abnormality degree.

[0073]

[Physical Configuration]

Fig. 5 is a diagram illustrating a physical configuration for implementing the operation support system 30 according to the present embodiment. The edge/cloud computing unit 32 can employ a known physical configuration and thus, will not be described. Hereinafter, a physical configuration of the operation support system 30 excluding the edge/cloud computing unit 32 will be described.

[0074]

The operation support system 30 includes a central processing unit (CPU) 30A corresponding to a calculation unit, a random access memory (RAM) 30B and a read only

memory (ROM) 30C corresponding to a storage unit, a communication unit 30D, an input unit 30E, and a display unit 30F. These configurations are connected to each other to be capable of transmitting and receiving data through a bus. While a case where the operation support system 30 is configured with one computer will be described in the present example, the operation support system 30 may be configured with a plurality of computers. For example, the display unit 30F may be configured with a plurality of displays. In addition, the configurations illustrated in Fig. 5 are merely an example, and a part of the configurations may not be provided. Furthermore, a part of the configurations may be provided at a remote location. For example, a part of the ROM 30C may be provided at a remote location and may be configured to be capable of communicating through a communication network.

[0075]

The CPU 30A is a calculation unit that performs control processing, calculation processing, and the like included in the present disclosure by executing a computer program or the like recorded in the ROM 30C or the like. The CPU 30A includes a processor. The CPU 30A receives various types of information (including the process data) from the RAM 30B, the ROM 30C, the communication unit 30D, the input unit 30E, and the like, and displays a

calculation processing result and the like on the display unit 30F or stores the calculation processing result and the like in the RAM 30B or in the ROM 30C.

[0076]

The RAM 30B functions as a primary storage such as a cache memory or a main memory in the storage unit and may be configured with, for example, a volatile semiconductor storage element such as an SRAM and a DRAM. The ROM 30C functions as a secondary storage in the storage unit and may be configured with, for example, a non-volatile semiconductor storage element such as a flash memory in which information can be electrically rewritten, or with an HDD in which information can be magnetically rewritten. For example, the ROM 30C may store the computer program and data for executing processing including each control and each calculation processing illustrated in the present disclosure in a non-transitory manner.

[0077]

The communication unit 30D is an interface for connecting the operation support system 30 to other devices such as the DCS 20. The communication unit 30D may be connected to a communication network such as the Internet.

[0078]

The input unit 30E receives input and the like of data (including selection of an important word and input of

additional guide information in the present disclosure) from the operator and may include, for example, a mouse, a keyboard, and a touch panel.

[0079]

The display unit 30F visually displays a calculation result of the CPU 30A and may be configured with, for example, a liquid crystal display (LCD).

[0080]

In the above physical configuration, each processing illustrated in the present embodiment including each function constituting the score display control unit 42 of the monitoring device 40 can be implemented by reading out and executing the computer program stored in the storage unit 44 via mainly the CPU 30A. In addition, each database constituting the storage unit 44 can be implemented from mainly the ROM 30C, and the display device 50 can be implemented from mainly the display unit 30F.

[0081]

[Display Method]

Hereinafter, a series of processes including a display method according to the present embodiment will be described.

[0082]

Fig. 6 is an example of a display screen (an example of a "first screen") of the display device 50 that displays

the score (an example of a "first score") indicating the operation state (an example of a "state quantity of a first element") of the entire plant (an example of the "first element") belonging to the highest tier (an example of the "first level"). The display device 50 is configured to be capable of displaying the score information or the like under control of the score display control unit 42.

[0083]

In a region AR11 of the display screen, a total score indicating the operation state of the entire plant is displayed. This score corresponds to the score of the evaluation element in the highest tier scored by the all element totaling unit 42B5. In the present embodiment, scoring is performed such that the numerical value is increased as deviation is increased in the embodiment. Thus, the total score of the entire plant may be referred to as the "total abnormality degree" or the like.

[0084]

In a region AR12 of the display screen, the evaluation element in the lower tier is displayed. In the tier structure according to the present embodiment, it is shown that the middle tier (an example of the "second level") that is the lower tier of the operation state of the entire plant, which is the evaluation element in the highest tier, is configured with seven evaluation elements such as member

quality (an example of a "second element"), the thermal state (an example of a "third element"), and efficiency (an example of the "second element").

[0085]

In a region AR13 of the display screen, a radar chart illustrating the score of each evaluation element in the lower tier is displayed. For example, the score of "member quality" (an example of a "second score") is 70, and the score of "thermal state" (an example of a "third score") is 40. Various display formats can be used. For example, the score of each evaluation element may be displayed using a bar graph. In addition, a value of the score may not be displayed. Even in a case where the value of the score is not displayed, comparison between the evaluation elements can be performed. Accordingly, the evaluation element for which a measure is to be taken can be specified.

[0086]

On the display screen, a score history of the total abnormality degree read out from the storage unit 44 for one year and a maximum value, a minimum value, and a mean value of the total abnormality degree for the past 24 hours are displayed. Accordingly, a trend of the operation state of the entire plant can also be identified.

[0087]

Since the total abnormality degree is 62, the operator can identify that the operation state of the plant 1 is not such a good state by seeing the display screen. In addition, since the score of "member quality" that is one of the evaluation elements in the lower tier is higher than those of the other evaluation elements, it can be estimated that "member quality" is a cause of abnormality.

[0088]

In a case where the operator presses a transition button illustrated as a right arrow in the drawing in a state where "member quality" is selected in the region AR12 of the screen, a transition is made to the display screen illustrated in Fig. 7.

[0089]

Fig. 7 is an example of the display screen (an example of a "second screen") of the display device 50 that displays a score indicating a state of "member quality" belonging to the middle tier.

[0090]

The score of "member quality" is displayed in a region AR21 of the display screen. This score corresponds to the score of the evaluation element in the middle tier scored by the middle tier totaling unit 42B4. This score is acquired in accordance with a predetermined logic based on the score of the evaluation element in the lower tier.

[0091]

In a region AR22 of the display screen, the evaluation element in the lower tier is displayed. In the tier structure according to the present embodiment, it is shown that the lowest tier (an example of a "third level") that is the lower tier of the member quality, which is the evaluation element in the middle tier, is configured with five evaluation elements such as "important item group 1" (an example of a "fourth element") and "important item group 2" (an example of the "fourth element"). Scoring of "important item group 1" is performed based on "pressure 1 score" and "temperature 1 score" (an example of a "third group") that are the monitoring items in the further lower tier.

[0092]

In a region AR23 of the display screen, the score (an example of a "fourth score") of each evaluation element in the lower tier is displayed. Since the scores of "important item group 1" and "important item group"3" are high, the operator can estimate that these are causes of abnormality. As illustrated in the drawing, it may be configured to be capable of displaying the score history of the evaluation element in the lower tier.

[0093]

In a case where the operator presses a transition button illustrated as a right arrow in the drawing in a state where "important item group 1" is selected in the region AR22 of the screen, a transition is made to the display screen illustrated in Fig. 8.

[0094]

Fig. 8 illustrates an example of the display screen on which the middle tier of the lower tier and the lowest tier are displayed at the same time. The evaluation element in the middle tier of the lower tier is "important item group 1". The evaluation elements in the lowest tier that is the lower tier of "important item group 1" are "pressure 1" and "temperature 1".

[0095]

In a region AR31 of the display screen, scores of "important item group 1", "pressure 1", and "temperature 1" are displayed. The score of "important item group 1" corresponds to the score of the evaluation element in the middle tier scored by the middle tier totaling unit 42B4. The scores of "pressure 1" and "temperature 1" correspond to the scores of the monitoring items that are the evaluation elements in the lowest tier scored by the item-specific abnormality degree indexing unit 42B2.

[0096]

In a region AR32 of the display screen, a scatter plot illustrating the process data of the monitoring item is also displayed.

[0097]

Score histories of "pressure 1" and "temperature 1" read out from the storage unit 44 are displayed on the display screen. Accordingly, trends of the states of the process data can be identified.

[0098]

As described above, according to the display device and the display method according to the present embodiment, in the case of monitoring or the like of the plant 1, which is the target object, from multiple state quantities of, for example, 100 or more, the operation state or the like of the target object can be evaluated in tiers with respect to a plurality of evaluation elements, and the state quantity that is the evaluation factor of a certain evaluation element can be easily specified.

[0099]

The display device and the display method may be configured to display and issue alarms in accordance with the score of each evaluation element.

[0100]

In addition, various modifications can be made to the present invention without departing from the concept

thereof. For example, within the scope of ordinary creativity of those skilled in the art, a part of components in the embodiment can be replaced with other known configurations, and other known configurations may be added. For example, indexing of the evaluation element may be executed based on the fuzzy inference in the middle tier totaling unit 42B4.

Reference Signs List

[0101]

1 Plant

2 Furnace

2a Fuel feed port

2b Gas outlet

2c Air supply line

2d Exhaust port

3 Cyclone

3a Exhaust gas flow path

4 Circulation material recovery pipe

4a Loop seal part

5 Rear flue

6 Furnace wall pipe

7 Pump

7a Pump

8 Steam drum

8a Downcast pipe

8b Saturated vapor pipe

10 Superheater

12 Coal economizer

30 Operation support system

30D Communication unit

30E Input unit

30F Display unit

32 Cloud computing unit

40 Monitoring device

42 Score display control unit

42A Process data acquisition unit

42B Scoring unit

42B1 Deviation distance acquisition unit

42B2 Item-specific abnormality degree indexing unit

42B3 Noise removal unit

42B4 Middle tier totaling unit

42B5 All element totaling unit

42C Score information display unit

42D Item-specific abnormality degree setting unit

42E Totaling method setting unit

44 Storage unit

50 Display device

100 Turbine

102 Condenser

- u1 Makeup water flow rate
- u2 Boiler feedwater flow rate
- u3 Boiler outlet vapor flow rate
- u4 Saturated vapor flow rate

CLAIMS

1. A display device configured to display:

a first score indicating a state quantity of a first element belonging to a first level from a plurality of types of state quantities of a target object;

a second score indicating a state quantity of a second element belonging to a second level from the state quantity of a first group that is a part of the plurality of types; and

a third score indicating a state quantity of a third element belonging to the second level from the state quantity of a second group that is a part of the plurality of types.

2. The display device according to claim 1,

wherein the display device is configured to display the first score, the second score, and the third score on the same screen.

3. The display device according to claim 1 or 2,

wherein the display device is configured to further display a fourth score indicating a state quantity of a fourth element belonging to a third level from the state

quantity of a third group that is a part of the first group.

4. The display device according to claim 3 citing claim 2,

wherein the display device is configured to:

display the second score and the fourth score on the same second screen; and

make a transition from the screen displaying the first score, the second score, and the third score to the second screen.

5. The display device according to any one of claims 1 to 4,

wherein the first score is acquired based on the second score and on the third score.

6. The display device according to any one of claims 1 to 5,

wherein the display device is configured to display at least one state quantity among the plurality of types of state quantities.

7. The display device according to any one of claims 1 to 6,

wherein the target object is a plant, and
the state quantity is process data.

8. A display method comprising:

a step of displaying a first score indicating a state quantity of a first element belonging to a first level from a plurality of types of state quantities of a target object;

a step of displaying a second score indicating a state quantity of a second element belonging to a second level from the state quantity of a first group that is a part of the plurality of types; and

a step of displaying a third score indicating a state quantity of a third element belonging to the second level from the state quantity of a second group that is a part of the plurality of types.

9. A control device that controls a display device to:

display a first score indicating a state quantity of a first element belonging to a first level from a plurality of types of state quantities of a target object on the display device;

display a second score indicating a state quantity of a second element belonging to a second level from the state

quantity of a first group that is a part of the plurality of types on the display device; and

display a third score indicating a state quantity of a third element belonging to the second level from the state quantity of a second group that is a part of the plurality of types on the display device.

10. A computer program causing a computer to generate a control instruction to:

display a first score indicating a state quantity of a first element belonging to a first level from a plurality of types of state quantities of a target object on a display device;

display a second score indicating a state quantity of a second element belonging to a second level from the state quantity of a first group that is a part of the plurality of types on the display device; and

display a third score indicating a state quantity of a third element belonging to the second level from the state quantity of a second group that is a part of the plurality of types on the display device.