

Description

Title of Invention: SYSTEM, METHOD, AND PROGRAM

Technical Field

[0001] The present invention relates to a system, a method, and a program.

RELATED ART

[0002] Petroleum refinement is known for refining crude oil to produce multiple petroleum products, as shown in Non-Patent Document 1, for example. Conventionally, when operating a relatively large-scale production site, such as a refinery where such petroleum refinement is performed, enterprise resource planning, manufacturing execution, process control, and the like are each performed independently using a system in which different groups (or departments) in an origination are independent from each other.

Non-Patent Document 1: Yokomizo, "Petroleum Refining Technology and Petroleum Supply and Demand Trends - Current Status and Future Prospects -," Japan Petroleum Institute for Natural Gas and Metals; Petroleum, Natural Gas Resources Information, September 20, 2017, Oil and Gas Review Vol. 51 No. 5, p. 1-20

[0003] When operating a production site, it is preferable to maintain accurate models continuously.

GENERAL DISCLOSURE

[0004] To solve the above problems, according to a first aspect of the present invention, provided is a system. The system may comprise a simulating section that simulates operation of at least a portion of a production site, based on a simulation model of the at least a portion of the production site. The system may comprise a monitoring section that monitors actual operation of the at least a portion of the production site. The system may comprise a calibrating section that calibrates the simulation model, based on a difference between the simulated operation and the actual operation. The system may comprise an updating section that updates a planning model used to generate a production plan for the production site, in response to the calibration of the simulation model.

[0005] The planning model may be a linear programming model.

[0006] The updating section may update at least one coefficient in a first-order expression used in the linear programming model.

[0007] The planning model and the simulation model may include a common parameter, and the updating section may update the at least one coefficient corresponding to the common parameter.

[0008] The simulating section may simulate the operation of the at least a portion of the

production site by inputting an update parameter for updating the planning model into the simulation model that has been calibrated, and the updating section may update the planning model based on a simulation result obtained using the update parameter.

[0009] The simulation model may be a steady state model.

[0010] The simulating section may simulate operation of one process unit at the production site.

[0011] The simulating section may simulate operation of a group of a plurality of process units at the production site.

[0012] If the difference exceeds a predetermined threshold value, the calibrating section may calibrate the simulation model.

[0013] The system may further comprise a detecting section that detects deterioration or improvement of the at least a portion of the production site, based on a parameter than has been calibrated in the simulation model.

[0014] The system may further comprise a judging section that judges whether to change a structure of the planning model, based on a difference between the production plan and the actual operation.

[0015] The production site may include a refinery that produces a plurality of petroleum products by refining crude oil.

[0016] The at least a portion of the production site may include at least one of a crude distillation unit, vacuum distillation unit, naphtha hydrotreating unit, catalytic reforming unit, benzene extraction unit, kerosene hydrotreating unit, diesel desulfurization unit, heavy oil desulfurization unit, fluid catalytic cracking unit, FCC gasoline desulfurization unit, thermal cracking unit, hydrocracker unit, or asphalt production unit.

[0017] According to a second aspect of the present invention, provided is a method. The method may comprise simulating an operation of at least a portion of a production site, based on a simulation model of the at least a portion of the production site. The method may comprise monitoring actual operation of the at least a portion of the production site. The method may comprise calibrating the simulation model, based on a difference between the simulated operation and the actual operation. The method may comprise updating a planning model used to generate a production plan for the production site, response to the calibration of the simulation model.

[0018] According to a third aspect of the present invention, provided is a program. The program may be executed by a computer. The program may cause the computer to function as a simulating section that simulates an operation of at least a portion of a production site, based on a simulation model of the at least a portion of the production site. The program may cause the computer to function as a monitoring section that monitors actual operation of the at least a portion of the production site. The program may cause the computer to function as a calibrating section that calibrates the

simulation model, based on a difference between the simulated operation and the actual operation. The program may cause the computer to function as an updating section that updates a planning model used to generate a production plan for the production site, response to the calibration of the simulation model.

[0019] The summary clause does not necessarily describe all necessary features of the embodiments of the present invention. The present invention may also be a sub-combination of the features described above.

Brief Description of Drawings

[0020] Fig. 1 shows an example of a total solution model 100 of an operation management system that may include the system according to the present embodiment as a portion thereof.

Fig. 2 shows an example of an oil refinement flow at a refinery 120R.

Fig. 3 shows an example of a block diagram of a system 300 according to the present embodiment.

Fig. 4 shows an example of a flow by which the system 300 according to the present embodiment calibrates the simulation model 325 and updates the planning model 315.

Fig. 5 shows an example of a block diagram of the system 300 according to a modification of the present embodiment.

Fig. 6 shows an example of a block diagram of the system 300 according to another modification of the present embodiment.

Fig. 7 shows an example of a flow by which the system 300 according to this modification of the present embodiment calibrates the simulation model 325 and updates the planning model 315.

Fig. 8 shows an example of a computer 2200 in which aspects of the present invention may be wholly or partly embodied.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0021] Hereinafter, some embodiments of the present invention will be described. The embodiments do not limit the invention according to the claims, and all the combinations of the features described in the embodiments are not necessarily essential to means provided by aspects of the invention.

[0022] A system according to the present embodiment relates to operation of a production site and, as an example, may realize some of the functions of a total solution model that realizes improvement of production efficiency, by organically integrating various functions from an enterprise resource planning (ERP) layer to a manufacturing execution system (MES) layer and a process control system (PCS) layer, and linking management information and control information. As an example, based on the

difference between a simulation result and the actual operating situation, the system according to the present embodiment calibrates a model that simulates the operation of the production site and updates the model for generating a production plan for the production site, in a portion of such a total solution model.

[0023] In the following description, an example is used in which the system according to the present embodiment is applied to the operation performed in a refinery and a petrochemical site, but the present embodiment is not limited to this. As an example, the system according to the present embodiment may be applied to operation of a production site other than a refinery or petrochemical site, for example.

[0024] Fig 1 shows an example of a total solution model 100 of an operation management system that may include the system according to the present embodiment as a portion thereof. The total solution model 100 comprehensively manages a plurality of production sites associated with the same organization (run by the same company, run by the same group of companies, or the like). For example, the total solution model 100 may comprehensively manage a plurality of refineries and a plurality of petrochemical sites that are run worldwide by the same group of companies. In the present drawing, the total solution model 100 includes a multi-site planning section 110, m refineries 120Ra to 120Rm (referred to collectively as the "refineries 120R"), and n petrochemical sites 120Ca to 120Cn (referred to collectively as the "petrochemical sites 120C"). If there is no particular reason to make a distinction, the refineries 120R and the petrochemical sites 120C are referred to collectively as production sites 120.

[0025] The multi-site planning section 110 comprehensively generates a production plan for each of the plurality of production sites 120 associated with the same organization. As an example, the multi-site planning section 110 comprehensively generates a production plan for each of the refineries 120Ra to 120Rm and the petrochemical sites 120Ca to 120Cm using a linear programming technique. Generally, with a mathematical model for determining work or intent, the problem of finding the value of a variable that gives the largest objective function under certain mathematical conditions is referred to as a mathematical programming problem. In particular, a case where the expression representing the objective function and the expression representing the mathematical conditions are represented by linear equations of variables is referred to as a linear programming problem. The technique for solving this problem is the linear programming technique.

[0026] More specifically, the linear programming technique is generally a technique for solving a problem of maximizing (or minimizing) an objective function shown by Math. 2, under constraint conditions shown by Math. 1. Here, x is an $(n \times 1)$ variable matrix in which each element is restricted non-negatively by Math. 1. Furthermore, when $i = 1, 2, \text{ or } 3$, A_i is an $(m_i \times n)$ coefficient matrix and b_i is an $(m_i \times 1)$ coefficient

matrix. Furthermore, c is an $(n \times 1)$ coefficient matrix. In this way, with the linear programming technique, a plurality of linear expressions are used, and each of the plurality of linear expressions is represented as a linear programming table. Each entry in the linear programming table is a coefficient for a respective one of a plurality of variables. The linear programming technique includes deriving a combination of variable values that maximize (or minimize) the objective function of Math. 2, under the constraint conditions shown by Math. 1, by repeatedly testing different combinations of a plurality of variables using matrix mathematics.

[Math.1]

$$\begin{aligned} A_1 x &\leq b_1, \\ A_2 x &\geq b_2, \\ A_3 x &= b_3, \\ x &\geq 0 \end{aligned}$$

[Math.2]

$$Z = {}^t c x$$

[0027] As an example, the multi-site planning section 110 acquires business information including crude oil quantity, crude oil type, crude oil price, product price, product demand, process unit availability, process unit maximum capacity, and the like via a network, various memory devices, user input, or the like. A "process unit" refers to a unit that performs any one of various processes needed to produce a product or semi-finished product from a raw material, or any processes associated with these various processes, at the production site 120. The business information such as described above includes a variable (e.g. crude oil price or the like) determined by a business environment or the like and a variable (e.g. crude oil amount or the like) determined by a business decision or the like, for example. It is difficult to purposefully change a variable determined by the business environment or the like, but a variable determined by a business decision or the like can be freely changed to a certain extent at according to the intent of the management. The multi-site planning section 110 derives a combination of variables that maximize the "gross profit", which is an example of the objective function, by performing a multi-site planning process a plurality of times while changing the values of variables determined by such management decisions or the like. In this case, the multi-site planning section 110 generates, for each of a plurality of production sites 120, a production plan including information such as oil

balance (input and output of the production site 120), economic balance (price and income for all input and output of the production site 120), gross profit, operating cost or net profit, energy balance (flow rate and heat quantity of fuel consumed in each process and in all processes in total), a process unit summary (summary of material balance and stream property), a marginal value (value indicating which constraint can realize a greater profit if relaxed), blend summary (summary of a mixture of components including the amount and property of each component), and reports concerning any of the above.

[0028] At this time, the multi-site planning section 110 generates, for each production site 120, a production plan for each of one or more relatively long multi-site plan intervals in a relatively long-term multi-site plan period. For example, the multi-site planning section 110 may generate, for each of the plurality of production sites 120, a production plan for each month in a period of the following three months. The multi-site planning section 110 supplies each of the plurality of production sites 120 with the production plans generated respectively for the plurality of production sites 120, via a network, various memory devices, user input, or the like.

[0029] The refineries 120R produce a plurality of petroleum products by refining crude oil. The petroleum products of the refineries 120R are described in detail further below. Each refinery 120R includes a site planning section 130, a site-wide simulating section 140, a process simulating section 150, a blending simulating section 155, an APC (Advanced Process Control) 160, a BPC (Blend Property Control) 165, an on-site process control section 170, and an off-site process control section 175. The above describes an example where each refinery 120R is provided with all of these function sections, but the present embodiment is not limited to this. As an example, some of these function sections, e.g. at least one of the site planning section 130, the site-wide simulating section 140, the process simulating section 150, or the blending simulating section 155, may be provided in at a location other than the refinery 120R.

[0030] The site planning section 130 generates a production plan for the production site 120 with which it is associated, using the linear programming technique, for example. At this time, the site planning section 130 may use a linear programming table having the same structure as the table used when the multi-site planning section 110 generated the production plan. As an example, the site planning section 130 acquires the production plan for the production site 120 with which the site planning section 130 is associated, from among the production plans generated by the multi-site planning section 110, via a network, various memory devices, user input, or the like. Furthermore, the site planning section 130 acquires business information that is more detailed than the business information used when the multi-site planning section 110 generated the production plan and tailored to the production site 120 with which the

site planning section 130 is associated, via a network, various memory devices, user input, or the like. Such detailed business information includes a variable determined by the business environment or the like at site level and a variable determined by a decision or the like made at site level, for example. It is difficult to purposefully change a variable determined by the business environment or the like at site level, but a variable determined by a business decision or the like made at site level can be freely changed to a certain extent according to the intent at site level. As an example, the site planning section 130 uses a linear programming table with the same structure as the table used by the multi-site planning section 110, to input parameter data that has been determined by the production plan generated by the multi-site planning section 110 and to perform the site planning process a plurality of times while changing the values of the variables determined by a decision or the like made at site level, in order to derive the combination of variable values that maximize the "gross profit", for example. The site planning section 130 then generates the production plan obtained in this case as the more detailed production plan tailored to the production site 120 with which the site planning section 130 is associated.

[0031] At this time, the site planning section 130 generates, for the production site 120 with which the site planning section 130 is associated, a production plan for each of one or more relatively short site planning intervals in a relatively short-term site planning period, compared to the site planning period of the production plan generated by the multi-site planning section 110. For example, the site planning section 130 may generate, for the production site 120 with which the site planning section 130 is associated, a production plan for each week in a period of the following one month. The site planning section 130 supplies the production plan that it generated to another function section or apparatus, via a network, various memory devices, user input, or the like.

[0032] If a problem would occur (e.g. if gross profit, production volume requirement, product quality specification, and tank storage capacity would drop below a threshold value or physical constraint) in the production plan of the production site 120 with which the site planning section 130 is associated when using the parameters determined by the production plan generated by the multi-site planning section 110, the site planning section 130 may provide feedback about this problem to the multi-site planning section 110 and generate a request to change a business decision made at the multi-site level.

[0033] The site planning section 130 may have a function of a scheduler that schedules operations at the production site 120 in units of single days or multiple days, for example, according to the production plan generated by this site planning section 130. The above describes an example in which the site planning section 130 has the

function of a scheduler, but the present embodiment is not limited to this. The refinery 120R may include a scheduler as another function section or apparatus differing from the site planning section 130. The scheduler may acquire basic schedule information including tank information, a transport ship schedule, a pipeline delivery schedule, a road or rail schedule, and the like, for example, via a network, various memory devices, user input, or the like. In a case where the scheduler is configured as a function section or apparatus differing from the site planning section 130, the scheduler acquires the production plan generated by the site planning section 130 via a network, various memory devices, user input, or the like. The scheduler then generates daily schedule information at the production site 120, for example, according to the acquired production plan, and supplies this daily schedule information to another function section or apparatus via a network, various memory devices, user input, or the like.

[0034] The site-wide simulating section 140 simulates the site-wide operation of the production site 120. That is, the site-wide simulating section 140 simulates the site-wide behavior of responses corresponding to input, output, and processing content at the production site 120. In the present drawing, the site-wide simulating section 140 performs site-wide simulation of the operation of on-site process units and off-site process units. As an example, "on-site" indicates the site where refining equipment is provided at the refinery 120R. Furthermore, "off-site" indicates a site where equipment around a tank yard that is outside where the refining equipment is provided at the refinery 120R, i.e. a site where ancillary equipment for receiving, storing, blending, and shipping crude oil, products, or semi-finished products is provided. The site-wide simulating section 140 acquires site information including information such as supply flow, product flow, temperature, pressure, and lab data concerning supply quality and product quality at the production site 120, via a network, various memory devices, user input, or the like. As an example, the site-wide simulating section 140 inputs the site information to a steady state model, simulates the operation of the production site 120, and outputs site-wide simulation results including information such as production amount, properties, site conditions, and performance at the production site 120. The steady state model is a model that outputs a constant result that does not change over time, in response to input that does not develop or change over time. At this time, the site-wide simulating section 140 may output the site-wide simulation results based at least partially on the schedule information generated by the scheduler. In other words, the site-wide simulating section 140 may output the site-wide simulation results obtained in a case where the production site 120 operates at least partially according to the schedule generated by the scheduler. Instead, the site-wide simulating section 140 may output the site-wide simulation results obtained in a case where the production

site 120 operates according to a schedule that is different from the schedule generated by the scheduler. The site-wide simulating section 140 supplies the output site-wide simulation results to another function section or apparatus via a network, various memory devices, user input, or the like.

[0035] The process simulating section 150 simulates the operation of each on-site process unit (group). That is, the process simulating section 150 simulates the behavior of reactions corresponding to input, output, and processing content of each on-site process unit (group). As an example, the process simulating section 150 acquires site information that is more detailed and tailored to each on-site process unit (group) compared to the linear programming in the site planning section 130, via a network, various memory devices, user input, or the like. Then, for example, the process simulating section 150 inputs the more detailed site information into the steady state model, simulates the operation of each on-site process unit (group), and outputs more detailed simulation results for each on-site process unit (group). At this time, the process simulating section 150 may output the simulation results of each on-site process unit (group) based at least partially on the schedule information generated by the scheduler. In other words, the process simulating section 150 may output the simulation results of each on-site process unit (group) obtained in a case where each on-site process unit (group) operates at least partially according to the schedule generated by the scheduler. Instead, the process simulating section 150 may output the simulation results of each on-site process unit (group) obtained in a case where each on-site process unit (group) operates according to a schedule different from the schedule generated by the scheduler. The process simulating section 150 supplies the output simulation results of each on-site process unit (group) to another function section or apparatus via a network, various memory devices, user input, or the like.

[0036] The blending simulating section 155 simulates the operation of each process unit (group) that is related to blend property control and located off-site. That is, the blending simulating section 155 simulates the behavior of reactions corresponding to input, output, and processing content each off-site process unit (group) related to blend property control. Blend property control refers to control performed to mix together each component at an off-site location and create products that satisfy certain standards with minimum cost and maximum throughput. The blending simulating section 155 acquires site information that is more detailed and tailored to each off-site process unit (group) related to blend property control, compared to the site information used when the site-wide simulating section 140 output the site-wide simulation results, via a network, various memory devices, user input, or the like. Then, for example, the blending simulating section 155 inputs the more detailed site information into the steady state model, simulates the operation of each off-site process unit (group) related

to blend property control, and outputs more detailed simulation results for each off-site process unit (group) related to blend property control. At this time, the blending simulating section 155 may output the simulation results of each off-site process unit (group) related to blend property control based at least partially on the schedule information generated by the scheduler. In other words, the blending simulating section 155 may output the simulation results of each off-site process unit (group) related to blend property control obtained in a case where each off-site process unit (group) related to blend property control operates at least partially according to the schedule generated by the scheduler. Instead, the blending simulating section 155 may output the simulation results of each off-site process unit (group) related to blend property control obtained in a case where each off-site process unit (group) related to blend property control operates according to a schedule different from the schedule generated by the scheduler. The blending simulating section 155 supplies the output simulation results of each off-site process unit (group) related to blend property control to another function section or apparatus via a network, various memory devices, user input, or the like.

[0037] The APC 160 is implemented for each process unit (group) that requires advanced control and is located on-site, and performs control at a higher level than the on-site process control section 170 that controls these process units (groups), for example. As an example, the APC 160 may set a target value that is a target for controlling the process units (groups), based on at least one of the schedule information generated by the scheduler, a logical unit grouping process simulation of 2-3 units, or the simulation results for each on-site process unit (group) output by the process simulating section 150. The APC 160 then controls the process variation in these process units (groups) by using feedback control or feedforward control in accordance with the target value to perform advanced control of the on-site process control section 170. The APC 160 does not need to be provided for processes that do not justify advanced control.

[0038] The BPC 165 is implemented for each process unit (group) that is related to blend property control and located off-site, and performs blend property control for each of these process units (groups) at a higher level than the off-site process control section 175 that controls these process units (groups), for example. As an example, the BPC 165 may perform higher level control of the off-site process control section 175 controlling the process units (groups) related to blend property control, based on at least one of the schedule information generated by the scheduler, the site-wide simulation results output by the site-wide simulating section 140, or the simulation results for each process unit (group) related to blend property control output by the blending simulating section 155.

[0039] The on-site process control section 170 is implemented for each on-site process

unit (group), and is a process control system that automatically manages the operations and processes of these process units (groups), using a computer, for example. The process control system referred to here includes a DCS (Distributed Control System), SCADA (Supervisory Control and Data Acquisition), a digital control system, a production information control system, process IT, a technical IT system, or the like. As an example, the on-site process control section 170 may control the on-site process units (groups) based on at least one of the schedule information generated by the scheduler, the site-wide simulation results output by the site-wide simulating section 140, the simulation results of each on-site process unit (group) output by the process simulating section 150, or the control information from the APC 160.

[0040] The off-site process control section 175 may be a system similar to the on-site process control section 170, for example. The off-site process control section 175 is implemented for each off-site process unit (group), and is a process control system that automatically manages the operations and processes of these process units (groups), using a computer. As an example, the off-site process control section 175 may control the off-site process units (groups) based on at least one of the schedule information generated by the scheduler, the site-wide simulation results output by the site-wide simulating section 140, the simulation results of each process unit (group) relating to blend property control output by the blending simulating section 155, or the control information from the BPC 165.

[0041] The petrochemical sites 120C produce a plurality of chemical products such as synthetic fiber, synthetic resin, and synthetic rubber, by causing a chemical reaction with raw material. The petrochemical sites 120C are similar to the refineries 120R, aside from not including the blending simulating sections 155 and the BPCs 165, and therefore further description is omitted.

[0042] In the total solution model 100, there is only one system and only one set of a work process and a model, and all of these are integrated by the flow and transfer of data or information. Accordingly, such a total solution model 100 ensures that the data is accurately and efficiently processed among different groups in an organization. Therefore, as an example, it is possible to realize a large-scale system in which information is linked between a main branch of a company and a refinery, and between multiple refineries, and in which work processes are streamlined and manual work is eliminated.

[0043] Fig. 2 shows an example of an oil refinement flow at a refinery 120R. At the refinery 120R, crude oil, which is a mixture of hydrocarbons with a wide boiling range, is refined to produce a plurality of petroleum products. Generally, at a refinery 120R, crude oil is distilled in a CDU (Crude Distillation Unit), and separated into fractions with different boiling ranges, i.e. a gas fraction, naphtha fraction, kerosene

fraction, light diesel oil fraction, heavy diesel oil fraction and residue fraction, according to a cutoff temperature. LP gas is produced from the gas fraction. The naphtha fraction is hydro-desulfurized by a naphtha hydrotreating unit and then catalytically reformed by a catalytic reforming unit (CRU), and benzene is separated therefrom by a benzene extraction unit to produce gasoline, naphtha, aromatics, and the like. The kerosene fraction is hydro-desulfurized in a kerosene hydrotreating unit to produce kerosene. The light diesel oil fraction is desulfurized in a diesel desulfurization unit to produce light oil. The heavy diesel oil fraction is hydro-desulfurized by a heavy oil direct desulfurization unit to produce heavy oil. Also, the heavy diesel oil fraction is separated into light and heavy fractions in a vacuum distillation unit (VDU). The light fraction separated by VDU is hydro-desulfurized in a heavy oil indirect desulfurization unit, then catalytically cracked in a fluid catalytic cracking (FCC) unit and hydro-desulfurized by an FCC gasoline desulfurization unit, to produce gasoline. Alternatively the light fraction separated by VDU is processed in a hydrocracker unit (HCU). On the other hand, the heavy fraction separated by VDU is pyrolyzed in a thermal cracking unit (Coker) to produce coke, and is also processed in an asphalt production unit to produce asphalt. In the petrochemical industry, naphtha is the main feedstock and olefins e.g. ethylene, propylene and aromatics, e.g. benzene, toluene, aromatic hydrocarbons of xylene (overall so-called BTX) are the main materials obtained.

[0044] In the total solution model 100, the on-site process units may include the units described above in the refinery 120R, for example, and the on-site process control section 170 may control the operations and processes of these units. Furthermore, the APC 160 may be implemented for each unit that is particularly important for the operation of the refinery 120R, such as the CDU, VDU, FCC, and CRU, among the units described above, for example.

[0045] Fig. 3 shows an example of a block diagram of a system 300 according to the present embodiment. The system 300 may realize a portion of the functions of the total solution model 100 shown in Fig. 1, for example. The system 300 according to the present embodiment calibrates the model for simulating the operation of the production site 120 and updates the model that generates the production plan of the production site 120, based on the difference between the simulation results and the actual operating situation.

[0046] The system 300 may be a computer such as a PC (personal computer), tablet computer, smartphone, work station, server computer, or general user computer, or may be a computer system in which a plurality of computers are connected. Such a computer system is also a computer, in a broad sense. The system 300 may be implemented in a virtual computer environment that can be executed in one or more

computers. Instead, the system 300 may be a specialized computer designed for the purpose of operation of the production site, or may be specialized hardware realized by specialized circuitry. If the system 300 is capable of connecting to the Internet, the system 300 may be realized by cloud computing.

[0047] The system 300 according to the present embodiment includes a planning section 310, a simulating section 320, an actual operation information acquiring section 330, a monitoring section 340, a calibrating section 350, and an updating section 360. Each block in the present drawing indicates a function block, and does not necessarily correspond to an actual device configuration or apparatus configuration. In other words, in the present drawing, just because function blocks are drawn as separate blocks, this does not limit the configuration to using separate devices or apparatuses for these functions. Furthermore, in the present drawing, just because a function block is shown by a single block, this does not limit the configuration to using a single device or apparatus for this function.

[0048] The planning section 310 includes a planning model 315, and generates the production plan for the production site 120 using the planning model 315. Here, the planning model 315 may be a linear programming model, for example. In other words, the planning model 315 derives a combination of variable values that maximize (or minimize) the objective function of Math. 2, under the restraint conditions shown by Math. 1, by repeatedly testing different combinations of a plurality of variables using matrix mathematics. For example, the planning section 310 may be at least one of the multi-site planning section 110 or the site planning section 130 in the total solution model 100. The planning section 310 acquires the business information via a network, various memory devices, user input, or the like, and generates the production plan using the acquired business information. The planning section 310 may supply the generated production plan and the schedule information corresponding to the generated production plan to another function section or apparatus, via a network, various memory devices, user input, or the like.

[0049] The simulating section 320 includes a simulation model 325 of at least a portion of the production site 120, and simulates the operation of at least a portion of the production site 120 based on this simulation model 325. Here, the at least a portion of the production site 120 may be a process unit in the production site 120, for example. Therefore, the simulation model 325 may be a process unit simulation model. As an example, the simulating section 320 may be the process simulating section 150 or the blending simulating section 155 in the total solution model 100. The simulating section 320 acquires the site information relating to the production site 120, via a network, various memory devices, user input, or the like. The simulating section 320 then uses the acquired site information to simulate the operation of at least a portion of the

production site 120, for example, and outputs the simulation results for at least a portion of the production site 120. The simulating section 320 then supplies the output simulation results to the monitoring section 340 and the updating section 360. Furthermore, in a case where the simulation model 325 is updated, the simulating section 320 supplies the updated parameter information to the updating section 360. The simulating section 320 may supply the output simulation results and updated parameter information to another function section or apparatus, via a network, various memory devices, user input, or the like.

- [0050] The actual operation information acquiring section 330 acquires the actual operation information, i.e. the performance, obtained when the production site 120 actually operates, via a network, various memory devices, user input, or the like. The actual operation information acquiring section 330 supplies the monitoring section 340 with the acquired actual operation information.
- [0051] The monitoring section 340 monitors the actual operation of at least a portion of the production site 120, using the actual operation information supplied from the actual operation information acquiring section 330. Then, when it is judged that calibration of the simulation model 325 is needed, the monitoring section 340 instructs the calibrating section 350 to calibrate the simulation model 325. Furthermore, when it is judged that an update of the planning model 315 is needed, the monitoring section 340 instructs the updating section 360 to update the planning model 315.
- [0052] The calibrating section 350 calibrates the simulation model 325, based on the difference between the operation simulated by the simulating section 320 and the actual operation monitored by the monitoring section 340.
- [0053] The updating section 360 updates the planning model 315, according to the calibration of the simulation model 325. Furthermore, the updating section 360 supplies a sub-model corresponding to the updated planning model 315 to the monitoring section 340. Here, the sub-model may be, for example, a model for each process unit. Each sub-model may include the same linear programming table as a subset for each process unit of the updated planning model 315.
- [0054] The following is a detailed description, using a flow, of a case where the simulation model 325 is calibrated and the planning model 315 is updated by these function sections.
- [0055] Fig. 4 shows an example of a flow by which the system 300 according to the present embodiment calibrates the simulation model 325 and updates the planning model 315.
- [0056] At step 410, the simulating section 320 simulates the operation of at least a portion of the production site 120 (e.g. a process unit in the production site 120), based on the simulation model 325 of at least a portion of the production site 120. Here, the

simulation model 325 may be a steady state model.

[0057] As an example, the simulating section 320 acquires the site information including information such as supply flow, product flow, temperature, pressure, and lab data concerning supply quality and product quality at the production site 120 obtained from mini tests or the like performed for a period of several hours, and at intervals of once or twice a month when full lab data is available, on the process units at the production site 120, via a network, various memory devices, user input, or the like, and inputs this site information to the simulation model 325 that is a steady state model. Next, as an example, the simulation model 325 simulates the behavior of reactions corresponding to the input, output, and processing content in at least a portion of the production site 120 in a case where the production site 120 operates according to the schedule information generated by the planning section 310. The simulating section 320 then outputs the simulation results including information such as the production quantity, property, site conditions, and performance of at least a portion of the production site 120 occurring in this case. The simulating section 320 supplies the monitoring section 340 with the simulation results obtained by simulating at least a portion of the production site 120.

[0058] Here, in the manner described above, the production site 120 may include a refinery 120R that produces a plurality of petroleum products by refining crude oil, for example. Accordingly, a portion of the production site 120 may include at least one of a crude distillation unit, vacuum distillation unit, naphtha hydrotreating unit, catalytic reforming unit, benzene extraction unit, kerosene hydrotreating unit, diesel desulfurization unit, heavy oil desulfurization unit (e.g. heavy oil indirect desulfurization unit and/or heavy oil direct desulfurization unit), fluid catalytic cracking unit, FCC gasoline desulfurization unit, thermal cracking unit, hydrocracker unit, or asphalt production unit in the refinery 120R. The simulating section 320 simulates the operation of one of an on-site process unit which may include these units described above, for example. At this time, the simulating section 320 may simulate the operation of one process unit at the production site 120, or may simulate the operation of a plurality of process units at the production site 120.

[0059] At step 420, the actual operation information acquiring section 330 acquires, via a network, the performance results as the actual operation information obtained when the production site 120 actually operates. The actual operation information acquiring section 330 supplies the monitoring section 340 with the acquired actual operation information. The monitoring section 340 then monitors the actual operation of at least a portion of the production site 120, using the actual operation information supplied from the actual operation information acquiring section 330.

[0060] At step 430, the monitoring section 340 makes a comparison between the

simulation results supplied from the simulating section 320 at step 410 and the actual operation information supplied from the actual operation information acquiring section 330 at step 420, and if the difference therebetween is less than or equal to a predetermined threshold value, judges that the simulated operation matches the actual operation and ends the process. On the other hand, if the comparison of step 430 indicates that this difference is greater than the predetermined threshold value, the monitoring section 340 judges that the simulated operation does not match the actual operation, judges that the simulation model 325 needs calibration, and instructs the calibrating section 350 to calibrate the simulation model 325. Furthermore, in response to the calibration of the simulation model 325, the monitoring section 340 judges that the planning model 315 needs to be updated, and instructs the updating section 360 to update the planning model 315.

[0061] When judging whether the simulated operation and the actual operation match, the monitoring section 340 may compare the simulation results and actual operation information to each other while focusing on any characteristic. For example, the monitoring section 340 may make the comparison while focusing on a prescribed characteristic such as the production amount or property, while focusing on another characteristic, or while focusing on a plurality of characteristics.

[0062] At step 440, the calibrating section 350 calibrates the simulation model 325 based on the difference between the simulated operation and the actual operation. For example, the calibrating section 350 updates adjustable parameter(s) in the model in a manner to minimize the difference between the simulated operation and the actual operation. In this way, when the difference between the simulated operation and the actual operation exceeds the predetermined threshold value, the calibrating section 350 may calibrate the simulation model 325. In this case, by making it possible for the user to set this threshold value, the trigger for the calibration of the simulation model 325 can be controlled.

[0063] At step 450, in response to the calibration of the simulation model 325 at step 440, the updating section 360 updates the planning model 315 and supplies a sub-model corresponding to the updated planning model 315 to the monitoring section 340. Then, the system 300 ends the process. At this time, the updating section 360 may update at least one coefficient in a first-order expression used in the linear programming model. Here, the planning model 315 and the simulation model 325 may include common parameters, and the updating section 360 may update at least one coefficient corresponding to a common parameter. In the manner described above, the planning model 315 includes a linear programming table in which each entry is a coefficient corresponding to a respective one of a plurality of variables. Some of the coefficients of each entry include at least one coefficient corresponding to a parameter common to the

planning model 315 and the simulation model 325. Therefore, as an example, the updating section 360 updates the planning model 315 by adjusting such a coefficient in the linear programming table. In this way, the updating section 360 can reflect the effect caused by the calibration of the simulation model 325 in step 440 in the planning model 315 as well.

[0064] Furthermore, when updating the planning model 315, the simulating section 320 inputs the update parameter for updating the planning model 315 into the simulation model 325 that has been calibrated at step 440 and simulates the operation of at least a portion of the production site 120, and the updating section 360 may update the planning model 315 based on the simulation results obtained using this update parameter. In other words, prior to actually updating the planning model 315, the updating section 360 may simulate the operation of at least a portion of the production site 120 in a case where the update parameter has been used, by using the calibrated simulation model 325 that was calibrated at step 440. In this way, the updating section 360 can judge the appropriateness of the update parameter in advance.

[0065] Conventionally, when performing worldwide operation of a large-scale production site 120, the enterprise resource planning and manufacturing execution have each been performed independently by different groups (or departments) in the organization and each using their own tools and systems that have no or limited integration with those in other groups (or departments). In other words, as an example, the planning model 315 is independently updated by the ERP layer and the simulation model 325 is updated independently by the MES layer, and this update and calibration are not reflected in each other. Therefore, despite the planning model 315 and the simulation model 325 being used in the same organization, the planning model 315 and the simulation model 325 operate with different settings. In contrast to this, according to the system 300 of the present embodiment, the simulation model 325 is calibrated based on the actual operating situation and the planning model 315 is updated in response to the calibration of the simulation model 325, and therefore the effect caused by calibrating the simulation model 325 is reflected in the planning model 315. Therefore, it is possible to accurately maintain the simulation model 325 for simulating the operation of the production site 120 and the planning model 315 for generating the production plan of the production site 120. In other words, the system 300 makes it possible to continue accurately modeling the production site 120. Accordingly, the system 300 makes it possible to reliably and quickly work through the PDCA (Plan-Do-Check-Act) cycle of operation management at the production site 120, and to maximize cooperation among a plurality of departments. Furthermore, by using such a system 300, it is possible to maximize objective function by optimizing the operations of a plurality of process units, for example.

- [0066] Fig. 5 shows an example of a block diagram of the system 300 according to a modification of the present embodiment. In FIG. 5, components that have the same function and configuration as in Fig. 3 are given the same reference numerals, and the descriptions include only differing points. The system 300 according to the present modification further includes a detecting section 510.
- [0067] The detecting section 510 detects deterioration or improvement of at least a portion of the production site 120, based on a parameter that has been calibrated in the simulation model 325. For example, if a calibrated parameter is a specified parameter relating to deterioration or improvement of a process unit, the detecting section 510 may judge that the process unit related to this specified parameter has deteriorated or improved. Furthermore, for a parameter that has been calibrated, if the change in a numerical value before and after calibration is greater than a predetermined threshold value, the detecting section 510 may judge that the process unit related to this parameter has deteriorated or improved. In other words, if there is a very large change in a parameter due to the calibration of the simulation model 325, the detecting section 510 may judge that the process unit relating to this parameter has deteriorated or improved. Furthermore, for a parameter that has been calibrated, if the interval between calibrations is less than a predetermined threshold value, the detecting section 510 may judge that the process unit relating to this parameter has deteriorated or improved. In other words, the detecting section 510 may judge that a process unit relating to a parameter that is calibrated very frequently has deteriorated or improved.
- [0068] In this way, the system 300 according to the present modification can, in addition to calibrating the simulation model 325 and updating the planning model 315, detect deterioration or improvement of at least a portion of the production site 120 based on a parameter used for calibration of the simulation model 325, and notify the user of this deterioration or improvement.
- [0069] Fig. 6 shows an example of a block diagram of the system 300 according to another modification of the present embodiment. In FIG. 6, components that have the same function and configuration as in Fig. 3 are given the same reference numerals, and the descriptions include only differing points. The system 300 according to the present modification further includes a judging section 610. The judging section 610 judges whether to change the structure of the planning model 315, based on the difference between the production plan and the actual operation.
- [0070] Fig. 7 shows an example of a flow by which the system 300 according to this modification of the present embodiment calibrates the simulation model 325 and updates the planning model 315. Steps 710 to 750 are the same as steps 410 to 450 of Fig. 4, and therefore descriptions of these steps are omitted.
- [0071] If the simulated operation and the actual operation of the process unit are judged to

be matching at step 730, for example, the monitoring section 340 moves the process to step 760. At step 760, the monitoring section 340 makes a comparison between the sub-model for the process unit supplied from the updating section at step 750 and the actual process unit operation information supplied from the actual operation information acquiring section 330 at step 720, and if it is judged that the sub-model and the actual operation match, ends the process. On the other hand, if it is judged that the sub-model and the actual operation do not match at step 760, the monitoring section 340 notifies the judging section 610 about this mismatch. At this time, when judging whether the sub-model and the actual operation match, the monitoring section 340 may make a comparison between the sub model for the process unit and the actual process unit operation while focusing on any kind of information.

[0072] At step 770, the judging section 610 judges whether to change the structure of the planning model 315, based on the difference between the production plan (that is the sub-model) and the actual operation. For example, if the difference between the process unit production plan and the actual operation exceeds a predetermined value, the judging section 610 judges that the structure of a subset for the process unit of the planning model 315 should be changed, and ends the process. As an example, the judging section 610 judges that the structure of the linear programming table itself should be changed, by adding a new linear equation or adding a new adjustment value, for example.

[0073] In this way, if only the planning model 315 differs from the actual operation while the simulation model 325 accurately models the actual operation of the production site 120, the system 300 according to this modification can notify the user about a change in the structure of the planning model 315.

[0074] Various embodiments of the present invention may be described with reference to flowcharts and block diagrams whose blocks may represent (1) steps of processes in which manipulations are performed or (2) sections of apparatuses responsible for performing manipulations. Certain steps and sections may be implemented by dedicated circuitry, programmable circuitry supplied with computer-readable instructions stored on computer-readable media, and/or processors supplied with computer-readable instructions stored on computer-readable media. Dedicated circuitry may include digital and/or analog hardware circuits and may include integrated circuits (IC) and/or discrete circuits. Programmable circuitry may include reconfigurable hardware circuits comprising logical AND, OR, XOR, NAND, NOR, and other logical manipulations, flip-flops, registers, memory elements, etc., such as field-programmable gate arrays (FPGA), programmable logic arrays (PLA), etc.

[0075] Computer-readable media may include any tangible device that can store instructions for execution by a suitable device, such that the computer-readable medium

having instructions stored therein comprises an article of manufacture including instructions which can be executed to create means for performing manipulations specified in the flowcharts or block diagrams. Examples of computer-readable media may include an electronic storage medium, a magnetic storage medium, an optical storage medium, an electromagnetic storage medium, a semiconductor storage medium, etc. More specific examples of computer-readable media may include a floppy disk, a diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), an electrically erasable programmable read-only memory (EEPROM), a static random access memory (SRAM), a compact disc read-only memory (CD-ROM), a digital versatile disk (DVD), a BLU -RAY (RTM) disc, a memory stick, an integrated circuit card, etc.

- [0076] Computer-readable instructions may include assembler instructions, instruction-set-architecture (ISA) instructions, machine instructions, machine dependent instructions, microcode, firmware instructions, state-setting data, or either source code or object code written in any combination of one or more programming languages, including an object oriented programming language such as Smalltalk, JAVA (registered trademark), C++, etc., and conventional procedural programming languages, such as the "C" programming language or similar programming languages.
- [0077] Computer-readable instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus, or to programmable circuitry, locally or via a local area network (LAN), wide area network (WAN) such as the Internet, etc., to execute the computer-readable instructions to create means for performing manipulations specified in the flowcharts or block diagrams. Examples of processors include computer processors, processing units, microprocessors, digital signal processors, controllers, microcontrollers, etc.
- [0078] FIG. 8 shows an example of a computer 2200 in which aspects of the present invention may be wholly or partly embodied. A program that is installed in the computer 2200 can cause the computer 2200 to function as or perform manipulations associated with apparatuses of the embodiments of the present invention or one or more sections thereof, and/or cause the computer 2200 to perform processes of the embodiments of the present invention or steps thereof. Such a program may be executed by the CPU 2212 to cause the computer 2200 to perform certain manipulations associated with some or all of the blocks of flowcharts and block diagrams described herein.
- [0079] The computer 2200 according to the present embodiment includes a CPU 2212, a RAM 2214, a graphics controller 2216, and a display device 2218, which are mutually connected by a host controller 2210. The computer 2200 also includes input/output

units such as a communication interface 2222, a hard disk drive 2224, a DVD-ROM drive 2226 and an IC card drive, which are connected to the host controller 2210 via an input/output controller 2220. The computer also includes legacy input/output units such as a ROM 2230 and a keyboard 2242, which are connected to the input/output controller 2220 through an input/output chip 2240.

- [0080] The CPU 2212 operates according to programs stored in the ROM 2230 and the RAM 2214, thereby controlling each unit. The graphics controller 2216 obtains image data generated by the CPU 2212 on a frame buffer or the like provided in the RAM 2214 or in itself, and causes the image data to be displayed on the display device 2218.
- [0081] The communication interface 2222 communicates with other electronic devices via a network. The hard disk drive 2224 stores programs and data used by the CPU 2212 within the computer 2200. The DVD-ROM drive 2226 reads the programs or the data from the DVD-ROM 2201, and provides the hard disk drive 2224 with the programs or the data via the RAM 2214. The IC card drive reads programs and data from an IC card, and/or writes programs and data into the IC card.
- [0082] The ROM 2230 stores therein a boot program or the like executed by the computer 2200 at the time of activation, and/or a program depending on the hardware of the computer 2200. The input/output chip 2240 may also connect various input/output units via a parallel port, a serial port, a keyboard port, a mouse port, or the like to the input/output controller 2220.
- [0083] A program is provided by computer readable media such as the DVD-ROM 2201 or the IC card. The program is read from the computer readable media, installed into the hard disk drive 2224, RAM 2214, or ROM 2230, which are also examples of computer readable media, and executed by the CPU 2212. The information processing described in these programs is read into the computer 2200, resulting in cooperation between a program and the above-mentioned various types of hardware resources. An apparatus or method may be constituted by realizing the manipulation or processing of information in accordance with the usage of the computer 2200.
- [0084] For example, when communication is performed between the computer 2200 and an external device, the CPU 2212 may execute a communication program loaded onto the RAM 2214 to instruct communication processing to the communication interface 2222, based on the processing described in the communication program. The communication interface 2222, under control of the CPU 2212, reads transmission data stored on a transmission buffering region provided in a recording medium such as the RAM 2214, the hard disk drive 2224, the DVD-ROM 2201, or the IC card, and transmits the read transmission data to a network or writes reception data received from a network to a reception buffering region or the like provided on the recording medium.
- [0085] In addition, the CPU 2212 may cause all or a necessary portion of a file or a

database to be read into the RAM 2214, the file or the database having been stored in an external recording medium such as the hard disk drive 2224, the DVD-ROM drive 2226 (DVD-ROM 2201), the IC card, etc., The CPU 2212 may then write back the processed data to the external recording medium.

[0086] Various types of information, such as various types of programs, data, tables, and databases, may be stored in the recording medium to undergo information processing. The CPU 2212 may perform various types of processing on the data read from the RAM 2214, which includes various types of manipulations, processing of information, condition judging, conditional branch, unconditional branch, search/replace of information, etc., as described throughout this disclosure and designated by an instruction sequence of programs, and writes the result back to the RAM 2214. In addition, the CPU 2212 may search for information in a file, a database, etc., in the recording medium. For example, when a plurality of entries, each having an attribute value of a first attribute associated with an attribute value of a second attribute, are stored in the recording medium, the CPU 2212 may search for an entry matching the condition whose attribute value of the first attribute is designated, from among the plurality of entries, and read the attribute value of the second attribute stored in the entry, thereby obtaining the attribute value of the second attribute associated with the first attribute satisfying the predetermined condition.

[0087] The above-explained program or software modules may be stored in the computer readable media on or near the computer 2200. In addition, a recording medium such as a hard disk or a RAM provided in a server system connected to a dedicated communication network or the Internet can be used as the computer readable media, thereby providing the program to the computer 2200 via the network.

[0088] While the embodiments of the present invention have been described, the technical scope of the invention is not limited to the above described embodiments. It is apparent to persons skilled in the art that various alterations and improvements can be added to the above-described embodiments. It is also apparent from the scope of the claims that the embodiments added with such alterations or improvements can be included in the technical scope of the invention.

[0089] The operations, procedures, steps, and stages of each process performed by an apparatus, system, program, and method shown in the claims, embodiments, or diagrams can be performed in any order as long as the order is not indicated by "prior to," "before," or the like and as long as the output from a previous process is not used in a later process. Even if the process flow is described using phrases such as "first" or "next" in the claims, embodiments, or diagrams, it does not necessarily mean that the process must be performed in this order.

List of Reference Numerals

[0090] 100: total solution model
110: multi-site planning section
120: production site
120R: refinery
120C: petrochemical site
130: site planning section
140: site-wide simulating section
150: process simulating section
155: blending simulating section
160: APC
165: BPC
170: on-site process control section
175: off-site process control section
300: system
310: planning section
315: planning model
320: simulating section
325: simulation model
330: actual operation information acquiring section
340: monitoring section
350: calibrating section
360: updating section
510: detecting section
610: judging section
2200: computer
2201: DVD-ROM
2210: host controller
2212: CPU
2214: RAM
2216: graphic controller
2218: display device
2220: input/output controller
2222: communication interface
2224: hard disk drive
2226: DVD-ROM drive
2230: ROM
2240: input/output chip
2242: keyboard

Claims

[Claim 1]

A system comprising:

a planning section that generates a production plan for a production site by using a planning model used to generate the production plan for the production site;

a simulating section that simulates operation of at least a portion of the production site, based on a simulation model to simulate the at least a portion of the production site;

a monitoring section that monitors actual operation of the at least a portion of the production site;

a calibrating section that calibrates the simulation model, based on a difference between the simulated operation and the actual operation; and

an updating section that updates the planning model, in response to the calibration of the simulation model.

[Claim 2]

The system according to Claim 1, wherein

the planning model is a linear programming model.

[Claim 3]

The system according to Claim 2, wherein

the updating section updates at least one coefficient in a first-order expression used in the linear programming model.

[Claim 4]

The system according to Claim 3, wherein

the planning model and the simulation model include a common parameter, and

the updating section updates the at least one coefficient corresponding to the common parameter.

[Claim 5]

The system according to any one of Claims 1 to 4, wherein

the simulating section simulates the operation of the at least a portion of the production site by inputting an update parameter for updating the planning model into the simulation model that has been calibrated, and

the updating section updates the planning model based on a simulation result obtained using the update parameter.

[Claim 6]

The system according to any one of Claims 1 to 5, wherein the simulation model is a steady state model.

[Claim 7]

The system according to any one of Claims 1 to 6, wherein the simulating section simulates operation of one process unit at the production site.

[Claim 8]

The system according to any one of Claims 1 to 6, wherein the simulating section simulates operation of a group of a plurality of process units at the production site.

[Claim 9]

The system according to any one of Claims 1 to 8, wherein if the difference exceeds a predetermined threshold value, the calibrating section calibrates the simulation model.

[Claim 10]

The system according to any one of Claims 1 to 9, further comprising:
a detecting section that detects deterioration or improvement of the at least a portion of the production site, based on a parameter that has been calibrated in the simulation model.

[Claim 11]

The system according to any one of Claims 1 to 10, further comprising:
a judging section that judges whether to change a structure of the planning model, based on a difference between the production plan and the actual operation.

[Claim 12]

The system according to any one of Claims 1 to 11, wherein the production site includes a refinery that produces a plurality of petroleum products by refining crude oil.

[Claim 13]

The system according to Claim 12, wherein the at least a portion of the production site includes at least one of a crude distillation unit,

vacuum distillation unit, naphtha hydrotreating unit, catalytic reforming unit, benzene extraction unit, kerosene hydrotreating unit, diesel desulfurization unit, heavy oil desulfurization unit, fluid catalytic cracking unit, FCC gasoline desulfurization unit, thermal cracking unit, hydrocracker unit, or asphalt production unit.

[Claim 14]

A method comprising:

generating a production plan for a production site by using a planning model used to generate the production plan for the production site;

simulating an operation of at least a portion of the production site, based on a simulation model to simulate the at least a portion of the production site;

monitoring actual operation of the at least a portion of the production site;

calibrating the simulation model, based on a difference between the simulated operation and the actual operation; and

updating the planning model, in response to the calibration of the simulation model.

[Claim 15]

A program that, when executed by a computer, causes the computer to function as:

a planning section that generates a production plan for a production site by using a planning model used to generate the production plan for the production site;

a simulating section that simulates an operation of at least a portion of the production site, based on a simulation model to simulate the at least a portion of the production site;

a monitoring section that monitors actual operation of the at least a portion of the production site;

a calibrating section that calibrates the simulation model, based on a difference between the simulated operation and the actual operation; and

an updating section that updates the planning model, in response to the calibration of the simulation model.