

[DESCRIPTION]

[Title of Invention] PORTFOLIO CREATION ASSISTANCE DEVICE AND
PORTFOLIO CREATION ASSISTANCE METHOD

[Technical Field]

5 [0001]

The present invention relates to a portfolio creation assistance device and a portfolio creation assistance method.

[Background Art]

[0002]

10 The concept of a so-called combinatorial optimization problem, which searches for a solution that maximizes or minimizes desired parameters under predetermined conditions, is applicable to complicated problems in the real world such as mitigation of traffic congestion and reduction of logistics cost in global
15 supply chains.

[0003]

On the other hand, such a problem entails an explosive number of candidate solutions; for this reason, it is difficult to solve the problem within a practicable time without a calculator
20 achieving considerable calculation performance such as a supercomputer and a quantum computer.

[0004]

For example, as a conventional technique related to a quantum computer, there have been proposed a technique (see PTL
25 1) and the like that are related to a calculator that enables high-speed computation for inverse problems and combinatorial optimization problems that require an exhaustive search. In this technique, a spin is used as a variable in the computation and a problem to be solved is set using spin-spin interaction and a
30 local field acting on each spin. All spins are caused to orient toward one direction by an external magnetic field at time $t=0$ and the external magnetic field is gradually reduced such that the external magnetic field becomes zero at time $t=\tau$. Each spin is time-evolved in such a way that the direction, which follows
35 an effective magnetic field determined by all actions of spin-spin

interaction and external magnetic fields of each site at time t , is determined. In this case, the direction of spin is not completely aligned in the effective magnetic field and is caused to be a quantum mechanically corrected direction such that the system is caused to maintain in an approximately ground state. [0005]

Meanwhile, as a technique for improving the efficiency of processing for a problem concerning determination of a portfolio of financial commodities among the problems in the real world as described above, there have been also proposed a program (see PTL 2) and the like that causes a computer to execute: an input procedure to input an expectation value of a return rate of an individual financial commodity, an individual variable factor that is a factor affecting return peculiarly to a financial commodity, a common variable factor that is a factor affecting return of all financial commodities, and a constraint parameter representing a constraint condition that should be taken into consideration in optimizing a utility function including a return rate of all the financial commodities and a risk affecting the return; a storage procedure to store the expectation value, the individual variable factor, the common variable factor, and the constraint parameter; a portfolio return rate calculation procedure to calculate a constraint expression of the return rate; an optimum portfolio seeking procedure to seek for a financial commodity to buy and a buying volume so as to maximize the utility function based on the expectation value, the individual variable factor, the common variable factor, the constraint parameter, and the constraint expression of the return rate by using mathematical programming which is a method of maximizing an objective function using a predetermined constraint expression; and a constraint condition determination procedure to determine whether the financial commodity to buy and the buying volume sought out in the seeking procedure satisfy a constraint expression related to the risk.

[Citation List]

[Patent Literature]

[0006]

[PTL 1] International Publication No. W02016/157333

[PTL 2] Japanese Patent Application Publication No. 2006-221679

5 [Summary of Invention]

[Technical Problem]

[0007]

10 In a case where a financial institution or the like holds multiple financial commodities, there is a need for optimizing a portfolio thereof to maximize the return. To address this, in the financial institution, a predetermined person in charge revises the portfolio depending on the situation or on a regular basis.

[0008]

15 On the one hand, there are a variety of factors including the profitability of each of financial commodities included in such a portfolio and various risks, and also the way of thinking about these factors greatly vary among the financial institutions.

20 [0009]

For this reason, if a general computer is employed to optimize a portfolio in which many financial commodities are combined, the calculation amount is increased in an exponential manner in accordance with the number of factors described above.
25 As a result, a huge amount of time is required to complete the calculation, or overflow occurs. In other words, it has been difficult to make a timely revision of a portfolio.

[0010]

30 On the other hand, there has been no proposal of a mode of appropriately applying the quantum computer technology to a portfolio. As a matter of course, in the current situation where no appropriate calculation result can be obtained with the aforementioned many factors taken into consideration, presenting the result to a user in an easily understandable form has been
35 neither implemented.

[0011]

Given the circumstances, an object of the present invention is to provide a technique that makes it possible to efficiently generate multiple portfolio candidates based on investment policies of each financial institution and present the portfolio candidates to a user in an easily understandable form.

[Solution to Problem]

[0012]

A portfolio creation assistance device, comprising: a storage unit storing information on each of financial commodities; and a computation unit performing a computation of an Ising model of a predetermined expression in which items of an expected return rate, a price drop risk, and a market sensitivity in a portfolio including combined predetermined ones of the financial commodities indicated by the information are combined with weights for the respective items, wherein the computation unit outputs portfolios each obtained for one of patterns of the weights for the respective items as a result of the computation to a predetermined device, the portfolios each minimizing a value of the predetermined expression.

[0013]

A portfolio creation assistance method, wherein an information processing device including a storage unit storing information on each of financial commodities performs: performing a computation of an Ising model of a predetermined expression in which items of an expected return rate, a price drop risk, and a market sensitivity in a portfolio including combined predetermined ones of the financial commodities indicated by the information are combined with weights for the respective items; and outputting portfolios each obtained for one of patterns of the weights for the respective items as a result of the computation to a predetermined device, the portfolios each minimizing a value of the predetermined expression.

[Advantageous Effects of Invention]

35 [0014]

According to the present invention, it is possible to efficiently generate multiple portfolio candidates based on the investment policies of each financial institution and present the portfolio candidates to a user in an easily understandable form.

5 [Brief Description of Drawings]

[0015]

[Fig. 1] Fig. 1 is a network configuration diagram including a portfolio creation assistance device of the present embodiment.

10 [Fig. 2] Fig. 2 is a diagram illustrating a hardware configuration example of the portfolio creation assistance device in the present embodiment.

[Fig. 3] Fig. 3 is a diagram illustrating a timing chart example in the present embodiment.

15 [Fig. 4] Fig. 4 is a diagram indicating a flowchart related to the fundamental concept in the present embodiment.

[Fig. 5] Fig. 5 is a diagram illustrating a data configuration example of financial commodity information of the present embodiment.

20 [Fig. 6] Fig. 6 is a diagram illustrating a data configuration example of weighting information of the present embodiment.

[Fig. 7] Fig. 7 is a diagram indicating a flow example of a portfolio creation assistance method in the present embodiment.

[Fig. 8] Fig. 8 is a diagram illustrating an output example 1 in the present embodiment.

25 [Fig. 9] Fig. 9 is a diagram illustrating an output example 2 in the present embodiment.

[Fig. 10] Fig. 10 is a diagram illustrating an output example 3 in the present embodiment.

30 [Fig. 11] Fig. 11 is a diagram illustrating an output example 4 in the present embodiment.

[Fig. 12] Fig. 12 is a diagram illustrating an output example 5 in the present embodiment.

[Fig. 13] Fig. 13 is a diagram illustrating an output example 6 in the present embodiment.

35 [Fig. 14] Fig. 14 is a diagram illustrating an output example 7

in the present embodiment.

[Fig. 15] Fig. 15 is a diagram illustrating an output example 8 in the present embodiment.

[Fig. 16] Fig. 16 is a diagram illustrating an output example 9
5 in the present embodiment.

[Description of Embodiments]

[0016]

---About Annealing Machine---

As described in PTL 1 described above, the applicant has
10 been developing the quantum computation technology to solve problems of exhaustive search problems based on big data (including the concept of combinatorial optimization problems), for example.

[0017]

15 In order to solve such exhaustive search problems, in general, there are great expectations for a quantum computer. A quantum computer includes a basic element called a quantum bit and implements "0" and "1" at the same time. Therefore, a quantum computer is capable of concurrently calculating all candidate
20 solutions as an initial value and has a possibility to implement an exhaustive search. However, a quantum computer needs to maintain quantum coherence over the entire calculation time.

[0018]

Against this background, a method called adiabatic quantum
25 computation (reference literature: E. Farhi, et al., "A quantum adiabatic evolution algorithm applied to random instances of an NP-complete problem," Science 292, 472 (2001).) has started to attract attention. This method is for converting a problem such that the ground state of a physical system becomes a solution and
30 obtaining the solution by finding the ground state.

[0019]

The Hamiltonian of the physical system in which a problem is set is H^p . Note that, at a time point when the computation is started, the Hamiltonian is not set to H^p , and a different
35 Hamiltonian H^0 that is easy to prepare because the ground state

is clear is set. Next, the transition of the Hamiltonian from H^0 to H^p is made taking enough time. With taking enough time, the system remains in the ground state, and the ground state of the Hamiltonian H^p can be obtained. This is the principle of the adiabatic quantum computation. Where the calculation time is τ , the Hamiltonian is Expression (1).

[Expression 1]

$$\hat{H}(t) = \left(1 - \frac{t}{\tau}\right) \hat{H}_0 + \frac{t}{\tau} \hat{H}_p$$

Then, time-evolution is made based on the Schrodinger equation of Expression (2), and thus a solution is obtained.

[0020]

[Expression 2]

$$i\hbar \frac{\partial}{\partial t} |\psi(t)\rangle = \hat{H}(t) |\psi(t)\rangle$$

15

The adiabatic quantum computation is also applicable to a problem that requires an exhaustive search and reaches a solution in a one-way process. However, if the calculation process needs to follow the Schrodinger equation of Expression (2), maintaining of quantum coherence is required as with a quantum computer.

20

[0021]

However, while a quantum computer repeats gate operations on one quantum bit or between two quantum bits, the adiabatic quantum computation allows for a concurrent interaction over the entire quantum bit system, and thus they have different ideas about coherence.

25

[0022]

For example, thinking of gate operation on a quantum bit. In this case, if there is an interaction between the quantum bit

and another quantum bit, this causes decoherence; however, since all quantum bits interact concurrently in the adiabatic quantum computation, no decoherence occurs in a case like this example. Reflecting this difference, the adiabatic quantum computation has
5 been thought to be more robust to decoherence than a quantum computer is.

[0023]

As described above, the adiabatic quantum computation is effective to a difficult problem that requires an exhaustive
10 search. Additionally, a spin is used as a variable in the computation, and a problem intended to be solved is set using spin-spin interaction and a local field acting on each spin.

[0024]

All spins are caused to orient toward one direction by an
15 external magnetic field at time $t=0$, and the external magnetic field is gradually reduced such that the external magnetic field becomes zero at time $t=\tau$.

[0025]

Each spin is time-evolved in such a way that the direction,
20 which follows an effective magnetic field determined by all actions of spin-spin interaction and external magnetic fields of each site at time t , is determined.

[0026]

In this case, the direction of spin is not completely aligned
25 in the effective magnetic field and is caused to be a quantum mechanically corrected direction such that the system is caused to maintain in an approximately ground state.

[0027]

Additionally, a term (relaxation term) that maintains each
30 spin in the original direction during the time-evolution is added to effective magnetic fields so as to improve the convergent of solution.

[0028]

As a portfolio creation assistance device in the present
35 embodiment, an annealing machine that performs the

above-described adiabatic quantum computation is assumed; however, as a matter of course, it is not limited thereto, and any device may be applicable as long as the device is capable of appropriately solving a combinatorial optimization problem by following a portfolio creation assistance method of the present invention. Specifically, not only hardware implemented by an electronic circuit (a digital circuit and the like) by an annealing method but also a method of implementation by a superconductive circuit and the like are included. Also, hardware that implements the Ising model by a method other than the annealing method may be applicable. For example, a laser network method (optical parametric oscillation), a quantum neural network, and the like are also included. Moreover, although it has a partially different idea as described above, it is also possible to implement the present invention by a quantum gate method that replaces the calculation performed with the Ising model with a gate such as the Hadamard gate, a rotation gate, and a controlled NOT gate.

[0029]

---Network Configuration---

An embodiment of the present invention is described in detail with reference to the drawings. Fig. 1 is a network configuration diagram including a portfolio creation assistance device 100 of the present embodiment.

[0030]

The portfolio creation assistance device 100 illustrated in Fig. 1 is a computer device that is capable of efficiently generating multiple portfolio candidates based on the investment policies of each financial institution and presenting the multiple portfolio candidates to a user in an easily understandable form; specifically, an annealing machine is assumed as an example.

[0031]

Note that, general description of an annealing machine is as already given based on PTL 1, and its details such as specific

configuration and operations are properly omitted (the same applies hereafter).

[0032]

5 The portfolio creation assistance device 100 of the present embodiment is data-communicably coupled with a user terminal 200 and a financial information distribution system 300 through an appropriate network 10 such as the Internet.

[0033]

10 Among the above, the user terminal 200 is a terminal that accepts provision of information on a portfolio of financial commodities from the portfolio creation assistance device 100.

[0034]

15 As a user of this user terminal 200, specifically, a person in charge as an institutional investor of such as a financial institution, an insurance company, and the like, or a general retail investor may be assumed.

[0035]

20 Additionally, the information on a portfolio of financial commodities provided by the portfolio creation assistance device 100 is information on an optimum portfolio (that is, a financial commodity group) that is identified by solving an Ising model (mathematical expression including, as variables, items of an expected return rate, a price drop risk, and a market sensitivity in each financial commodity) for each of the portfolio candidates
25 in which various financial commodities are combined at a predetermined ratio (that is, a holding ratio) for each pattern of weighting on the items of the expected return rate, the price drop risk, and the market sensitivity (such as the interest delta and the exchange delta) (the weighting depending on the viewpoint
30 considered important by the user).

[0036]

35 In this case, the values of the expected return rate, the price drop risk, and the market sensitivity (such as the interest delta and the exchange delta) in the optimum portfolio are presented, naturally.

[0037]

Note that, the portfolio creation assistance device 100 is a device that outputs the information on the optimum portfolios for the respective patterns of weighting (the viewpoints
5 considered important by the user) as described above in such a way that the information can be easily compared and considered among the optimum portfolios.

[0038]

That is, based on the values of the items of the expected
10 return rate, the price drop risk, and the market sensitivity, in each optimum portfolio (hereinafter, simply referred to as a portfolio), the portfolio creation assistance device 100 plots the position of each of the portfolios on at least one of a plane defined by two axes of the price drop risk and the expected return
15 rate, a plane defined by two axes of the expected return rate and the interest delta as the market sensitivity, and a plane defined by two axes of the expected return rate and the exchange delta as the market sensitivity, and outputs the plane on which the plotting is performed to an appropriate device such as the user
20 terminal 200. In this case, a corresponding efficient frontier curve is drawn on the plane on which the plotting is performed (an already-existing technique may be applied for the generation and the like of the efficient frontier curve).

[0039]

25 With such output processing being performed, the properties of each portfolio are clearly presented from multiple viewpoints, and the portfolio designing operation by a person in charge in a financial institution is effectively assisted.

[0040]

30 Additionally, predetermined highlighting processing may be performed on a portfolio out of the portfolios plotted on the plane defined by the two axes of the price drop risk and the expected return rate that is a portfolio having a lower price drop risk and a higher return than those of a current portfolio of the user
35 (as a matter of course, the user provides in advance the portfolio

creation assistance device 100 with the financial commodities and its holding ratio and the values of the items of the expected return rate, the price drop risk, and the market sensitivity) and being plotted on a region above the efficient frontier curve.

5 [0041]

As the above-described highlighting processing, although it is not particularly limited, processing of making the color, shape, size, pattern, pattern of blinking or flashing, and the like of a plot (point) of a corresponding portfolio different from that of other portfolios may be assumed, for example.

10 [0042]

With such output processing being performed, it is possible to clearly present a new portfolio that can be expected to be improved from a current portfolio in both the expected return rate and risk.

15 [0043]

Note that, the portfolio creation assistance device 100 finds a specific portfolio plotted on a region above the efficient frontier curve out of the portfolios plotted on the above-described plane defined by the two axes of the price drop risk and the expected return rate and calculates the value of return on risk by dividing the value of the expected return rate by the value of the price drop risk of the portfolio.

20 [0044]

In this case, for the above-described specific portfolio, the portfolio creation assistance device 100 arranges an object having an attribute according to the magnitude of the value of return on risk on the plane defined by two axes of the interest delta and the exchange delta and outputs the specific portfolio.

25 30 [0045]

As this object, a display object in a predetermined shape such as circle and rectangle can be assumed, for example. Additionally, its attribute is assumed to be a size, color, shape, pattern, pattern of blinking or flashing, and the like according to the magnitude of the value of return on risk.

35

[0046]

With this, it is possible to express a portfolio based on all the viewpoints of the expected return rate, the price drop risk, and the market sensitivity (the interest delta and the exchange delta), that is, in a four-dimensional event, and present the portfolio to the user while clearly distinguishing it among portfolios.

[0047]

Moreover, the portfolio creation assistance device 100 applies buying and selling costs on which information is held in advance to financial commodities that make the difference between at least one of the above-described portfolios and the current portfolio of the user to identify the cost required for portfolio change from the current portfolio to an optimum portfolio, and outputs the information on the cost. With this, it is possible to present the information on the cost for changing a portfolio, and the user is allowed to easily perform the portfolio creation operation in terms of a comprehensive viewpoint including not only the above-described information on the items but also the cost.

[0048]

A person in charge in a financial institution or the like who is provided with such various kinds of information on portfolios can make a determination on selecting an appropriate portfolio not only simply and accurately but also quickly.

[0049]

Note that, conceivable patterns as the above-described pattern of weighting are a pattern in which the items are evaluated with an equal importance (an equal weight value is assigned to the items), a pattern in which the return and the price drop risk are considered more important and the interest delta and the exchange delta are considered less important (weight values for the items of the return and the price drop risk > weight values for the interest delta and the exchange delta), and a pattern in which the return is considered most important (a weight value for the item of the return > weight values for the items of the price

drop risk, the interest delta, and the exchange delta). Note that, these patterns are non-limiting examples.

[0050]

On the other hand, the financial information distribution system 300 is a system that distributes information on various financial commodities to the portfolio creation assistance device 100.

[0051]

As this financial information distribution system 300, a server device operated by an organization holding information on financial commodities such as various financial institutions, brokerage companies, governmental institutions, and the like can be assumed.

[0052]

As the above-described various financial commodities, stocks, futures instruments, foreign exchanges, and the like can be assumed, for example. As the information held, the market sensitivity such as the expected return rate, the price drop risk, the interest delta, and the exchange delta, the commodity price (example: the stock index, the commodity futures price, the foreign exchange rate, the foreign exchange forward rate, the long-short outstanding position ratio, the volatility of various indexes, the risk reversal, and the like), various commissions (example: the buying and selling commission, the management commission), and the like can be assumed.

[0053]

Conventionally, in order to calculate an optimum portfolio, the calculation amount is increased in an exponential manner in accordance with an increase in elements such as variations of weighting on the above-described items and combination patterns of financial commodities, and it takes a long time to complete the calculation. However, with the portfolio creation assistance device 100 using an annealing machine being employed, it is possible to perform calculation without much dependency on the increase in elements.

[0054]

---Hardware Configuration---

Additionally, a hardware configuration of the portfolio creation assistance device 100 of the present embodiment is implemented as illustrated in Fig. 2 described below. That is, the portfolio creation assistance device 100 includes a storage unit 101, a memory 103, a computation unit 104, and a communication unit 105.

[0055]

10 Among the above, the storage unit 101 includes an appropriate non-volatile storage element such as an SSD (solid state drive) or a hard disk drive. Meanwhile, the memory 103 includes a volatile storage element such as a RAM.

[0056]

15 Additionally, the computation unit 104 is a CPU that executes a program 102 held in the storage unit 101 by reading the program 102 into the memory 103 to make an overall control of the device itself and also performs various kinds of determination, computation, and control processing.

20 [0057]

Moreover, the communication unit 105 includes a network interface card that is coupled with the network 10 and is responsible for communication processing with other devices such as the user terminal 200 and the financial information distribution system 300.

[0058]

Note that, when the portfolio creation assistance device 100 is a stand-alone machine, it is preferable for the portfolio creation assistance device 100 to further include an input unit (including a keyboard, a mouse, and so on) to receive key inputs and sound inputs from the user and an output unit such as a display to display processing data.

[0059]

35 Additionally, the storage unit 101 stores therein not only the program 102 for implementing a function required to operate

as the portfolio creation assistance device of the present embodiment but also financial commodity information 125 and weighting information 126 at least. Note that, details of such information are described later.

5 [0060]

Moreover, the program 102, that is, an algorithm implementing operations to be an annealing machine, holds information on an Ising model 1021, which is a problem intended to be solved. This Ising model 1021 is set in advance by a manager
10 or the like based on a portfolio from which the information is provided, various information on financial commodities forming the portfolio, the portfolio investment policies of a target financial institution, and the like.

[0061]

15 Note that, the adiabatic quantum computation described in the general description of an annealing machine is also called the quantum annealing as another name, which is the concept of the classical annealing developed into the quantum mechanics. In other words, it is also possible to construe that the adiabatic
20 quantum computation is originally capable of operating classically, and quantum mechanic effects are added thereto in order to improve the performances of high speed and percentage of obtaining correct solutions. Accordingly, the present invention implements a computation method and device that are
25 classic but have the quantum mechanic effects by keeping the computation unit itself classic and introducing a parameter that is quantum mechanically determined in the computation process.

[0062]

Based on the above-described concept, in the following
30 examples, a classical algorithm that obtains the ground state as a solution and a device that implements the algorithm are described while describing the relevance with the adiabatic quantum computation.

[0063]

35 In the portfolio creation assistance device 100 with such

premises, N variables s_j^z ($j = 1, 2, \dots, N$) have a range of $-1 \leq s_j^z \leq 1$, and a local field g_j and an intervariable interaction J_{ij} ($i, j = 1, 2, \dots, N$) set a problem.

[0064]

5 Additionally, the computation unit 104 divides a time into m and performs the computation discretely from $t=t_0$ ($t_0 = 0$) to t_m ($t_m = \tau$), and in order to obtain a variable $S_j^z(t_k)$ at each time t_k , the computation unit 104 uses a value of a variable $S_j^z(t_{k-1})$ ($i = 1, 2, \dots, N$) at previous time t_{k-1} and a coefficient $9p_{ina}$ or $9p_{inb}$ of a relaxation term to obtain $B_j^z(t_k) = \{ \sum_i J_{ij} S_i^z(t_{k-1}) + g_j + \text{sgn}(s_j^z(t_{k-1})) \cdot 9p_{ina} \} \cdot t_k / \tau$ or $B_j^z(t_k) = \{ \sum_i J_{ij} S_j^z(t_{k-1}) + g_j + 9p_{inb} \cdot S_j^z(t_{k-1}) \} \cdot t_k / \tau$, defines a function f such that the range of the above-described variable $S_j^z(t_k)$ becomes $-1 \leq s_j^z(t_k) \leq 1$ to obtain $S_j^z(t_k) = f(B_j^z(t_k), t_k)$, makes
10 the above-described variable S_j^z close to -1 or 1 while advancing the time step from $t=t_0$ to $t=t_m$, and defines a solution as $S_j^{zd} = -1$ if $s_j^z < 0$ eventually, or as $S_j^{zd} = 1$ if $S_j^z > 0$.

[0065]

20 The coefficient g_{pinb} is a value that is 50% to 200% of an average value of $|J_{ij}|$, for example. Additionally, regarding the local field g_j for setting a problem, it is also possible to add a correction term $\delta g_j'$ to g_j' for only a site j' so as to increase the magnitude of g_j' for only the site j' . Moreover, the correction term $\delta g_j'$ is a value that is 10% to 100% of the average
25 value of $|J_{ij}|$, for example.

[0066]

Subsequently, the fundamental principle of an annealing machine is described through a transition started from a quantum mechanical description to the classical form.

30 [0067]

A ground state search problem of the Ising spin Hamiltonian provided by Expression (3) includes a problem categorized as so-called NP-hardness and is thereby known as a useful problem (literature: F. Barahona, "On the computational complexity of
35 Isingspin glass models," J. Phys. A: Math. Gen. 15, 3241 (1982).).

[0068]

[Expression 3]

$$\hat{H}_p = -\sum_{i>j} J_{ij} \hat{\sigma}_i^z \hat{\sigma}_j^z - \sum_j g_j \hat{\sigma}_j^z$$

5 where J_{ij} and g_j are problem setting parameters, σ^z is a z-component of Pauli spin matrices and takes an eigenvalue of ± 1 , and i and j each denote a site of a spin. An Ising spin is a variable that can take only ± 1 as a value, and Expression (3) is an Ising spin system because the eigenvalue of σ^z is ± 1 .

10 [0069]

The Ising spin in Expression (3) is not necessarily a spin literally and may be anything physical as long as the Hamiltonian is described with Expression (3).

[0070]

15 For example, it is also possible to associate whether a portfolio of financial commodities is employed or not employed with ± 1 or to associate high and low of a logic circuit with ± 1 , and it is also possible to associate vertically polarized waves and horizontally polarized waves of light with ± 1 or to associate
20 phases of 0 and π with ± 1 .

[0071]

As with the adiabatic quantum computation, the method exemplified herein prepares a computation system in the ground state of the Hamiltonian provided by Expression (4) at time $t=0$.

25 [0072]

[Expression 4]

$$\hat{H}_0 = -\gamma \sum_j \hat{\sigma}_j^x$$

where γ is a proportionality constant determined depending

on the magnitude of an external stimulus uniformly applied onto all sites j , and σ^j_x is an x-component of Pauli spin matrices. When the computation system is the spin itself, the external stimulus means a magnetic field.

5 [0073]

Expression (4) is comparable to applying of a transverse magnetic field, and the ground state is obtained when all spins are directed to an x direction ($\gamma > 0$). The Hamiltonian for setting a problem is defined as the Ising spin system including only the z-component; however, Expression (4) includes the x-component of the spin. Accordingly, the spin in the computation process is not Ising but vectorial (Bloch vector). At $t=0$, the computation is started with the Hamiltonian of Expression (4), and the Hamiltonian is changed gradually as time t progresses, and eventually, the Hamiltonian described as Expression (3) is

15 [0074]

[Expression 5]

$$\hat{H} = -\mathbf{B} \cdot \hat{\boldsymbol{\sigma}}$$

20

where $\hat{\boldsymbol{\sigma}}$ denotes three components of Pauli spin matrices as a vector. The ground state is obtained when the spin is directed to a magnetic field direction and can be expressed as $\langle \hat{\boldsymbol{\sigma}} \rangle = \mathbf{B}/|\mathbf{B}|$ where $\langle \cdot \rangle$ denotes a quantum mechanical expectation value. In the adiabatic process, the ground state is intended to be maintained constantly; therefore, the direction of the spin always follows the direction of the magnetic field.

25 [0075]

The above discussion can be expanded to a multi-spin system. At $t=0$, the Hamiltonian is provided by Expression (4). This means that a magnetic field $\mathbf{B}^x = \gamma$ is uniformly applied onto all spins. At $t>0$, the x-component of the magnetic field is gradually weakened, and $\mathbf{B}^x = \gamma(1 - t/\tau)$ is obtained. For the z-component,

30

an effective magnetic field is expressed as Expression (6) because there is the spin-spin interaction.

[0076]

[Expression 6]

$$\hat{B}_j^z(t) = \frac{t}{\tau} \left(\sum_{i \neq j} J_{ij} \hat{\sigma}_i^z + g_j \right)$$

5

Since the direction of the spin can be defined by $\langle \sigma^z \rangle / \langle \sigma^x \rangle$, the direction of the spin is defined based on Expression (7) if the direction of the spin follows the effective magnetic field.

10 [0077]

[Expression 7]

$$\langle \hat{\sigma}_j^z \rangle / \langle \hat{\sigma}_j^x \rangle = \langle \hat{B}_j^z(t) \rangle / \langle \hat{B}_j^x(t) \rangle$$

Expression (7) is a quantum mechanical description but has an expectation value; therefore, unlike Expressions (1) to (6), Expression (7) is a relational expression related to the classical amount.

15

[0078]

In the classical system, there is no non-local correlation of the quantum mechanics (quantum sewing); for this reason, the direction of the spin should be completely determined based on the local field of each site, and Expression (7) determines the behavior of the classical spin system. In the quantum system, there is non-local correlation; for this reason, Expression (7) is deformed, which is described later, and now the classical system defined by Expression (7) is described in order to describe the fundamental mode of the invention.

20

25

[0079]

Fig. 3 illustrates a timing chart (1) for obtaining the ground state of a spin system. Since the description in Fig. 3

30

is related to the classical amount, the spin in the site j is denoted by s_j instead of σ^j . Additionally, according to the above, an effective magnetic field B_j in Fig. 3 is a classical amount. At $t=0$, the effective magnetic field B_j directed to the right is applied to all sites, and all the spins S_j are initiated to be directed to the right.

[0080]

As time t progresses, a magnetic field in a z -axis direction and the spin-spin interaction are gradually added, and eventually, the spins are directed to a $+z$ direction or a $-z$ direction, and the z -component of the spin S_j becomes $s_j^z = +1$ or -1 . Time t is preferably continuous; however, in the practical computation process, time t may be discrete so as to improve the convenience. The discrete case is described below.

[0081]

The spin exemplified herein is a vectorial spin since there are added not only the z -component but also the x -component. Also, the behavior as a vector can be understood with reference to Fig. 3. There has been no description of a y -component; this is because the external stimulus direction is set in an xz plane and thus no y -component exists in the external stimulus, and accordingly $\langle \sigma^y \rangle = 0$ is obtained.

[0082]

As the spin for the computation system, three-dimensional vectors of a magnitude of 1 (this is called Bloch vector, which can describe the state with a point on a spherical surface) is assumed; however, with the setting of axes in the illustrated example, only two dimensions may be taken into consideration (the state can be described with a point on a circle).

[0083]

Additionally, since γ is constant, $B_j^x(t) > 0$ ($\gamma > 0$) or $B_j^x(t) < 0$ ($\gamma < 0$) is satisfied. In this case, a two-dimensional spin vector can be described with only a semicircle, and if S_j^z is designated with $[-1, 1]$, a two-dimensional spin vector is defined with one variable of S_j^z . Accordingly, in the example herein,

the spin is a two-dimensional vector, but can also be described as a one-dimensional continuous variable having a range of [-1, 1].

[0084]

5 In the timing chart in Fig. 3, an effective magnetic field of each site is obtained at time $t=tk$, and the value is used to obtain the direction of the spin at $t=tk$ by Expression (8).

[0085]

[Expression 8]

$$10 \quad s_j^z(t_k) / s_j^x(t_k) = B_j^z(t_k) / B_j^x(t_k)$$

Since Expression (8) is a rewritten form of Expression (7) into a description related to the classical amount, no signs of $\langle \cdot \rangle$ are used.

15 [0086]

Next, an effective magnetic field at $t=tk+1$ is obtained by using the value of the spin at $t=tk$. The effective magnetic fields at the times are specifically described as Expressions (9) and (10).

20 [0087]

[Expression 9]

$$B_j^x(t_{k+1}) = \left(1 - \frac{t_{k+1}}{\tau} \right) \gamma$$

[Expression 10]

$$25 \quad B_j^z(t_{k+1}) = \frac{t_{k+1}}{\tau} \left(\sum_{i \neq j} J_{ij} s_i^z(t_k) + g_j \right)$$

Hereinafter, spins and effective magnetic fields are

alternately obtained in accordance with the procedure schematically illustrated in the timing chart in Fig. 3.

[0088]

In the classical system, the magnitude of a spin vector is
 5 1. In this case, each component of the spin vector is described as $S_j^z(tk) = \sin\theta$ and $S_j^x(tk) = \cos\theta$ by using a parameter θ defined by $\tan\theta = B_j^z(tk)/B_j^x(tk)$.

[0089]

The above expressions are rewritten as $S_j^z(tk) =$
 10 $\sin(\arctan(B_j^z(tk)/B_j^x(tk)))$ and $S_j^x(tk) =$
 $\cos(\arctan(B_j^z(tk)/B_j^x(tk)))$.

[0090]

As it is clear from Expression (9), a variable of $B_j^x(tk)$ is only tk , and τ and γ are constants. Accordingly, $S_j^z(tk) =$
 15 $\sin(\arctan(B_j^z(tk)/B_j^x(tk)))$ and $S_j^x(tk) =$
 $\cos(\arctan(B_j^z(tk)/B_j^x(tk)))$ can also be expressed in a generalized form like $S_j^z(tk) = f_1(B_j^z(tk), tk)$ and $S_j^x(tk) = f_2(B_j^z(tk), tk)$ as functions in which $B_j^z(tk)$ and tk are variables.

[0091]

20 Since the spin is described as a two-dimensional vector, there are two components of $S_j^z(tk)$ and $S_j^x(tk)$; however, if $B_j^z(tk)$ is determined based on Expression (10), $S_j^x(tk)$ is unnecessary.

[0092]

25 This corresponds to the fact that the spin state can be described only with $S_j^z(tk)$ having a range of $[-1, 1]$. The eventual solution S_j^{zd} needs to be $S_j^{zd} = -1$ or 1 , and $S_j^{zd} = 1$ is obtained if $S_j^z(\tau) > 0$, while $S_j^{zd} = -1$ is obtained if $S_j^z(\tau) < 0$.

30 [0093]

Fig. 4 indicates a flowchart in which the above-described algorithms are listed. In this case, $t_m = \tau$. Each of steps s_1 to s_9 in the flowchart in Fig. 4 corresponds to processing at a corresponding time in the timing chart in Fig. 3 from time $t=0$
 35 to $t=\tau$. That is, the steps s_2 , s_4 , and s_6 in the flowchart

correspond to Expressions (9) and (10) described above in $t=t_1$, t_k+1 , and t_m , respectively. The eventual solution is determined in the step s8 with $S_j^{zd} = -1$ being obtained if $s_j^z < 0$, and $S_j^{zd} = 1$ being obtained if $S_j^z > 0$ (s9).

5 [0094]

So far, how is a problem expressed by Expression (3) is solved has been described. Next, how is a specific problem expressed by Expression (3) including the local field g_j and the intervariable interaction J_{ij} ($i, j = 1, 2, \dots, N$) is described using a specific example.

10 [0095]

As the specific problem herein, that is, the Ising model 1021, a problem that estimates a combination of financial commodities at a predetermined holding ratio that minimizes the result of an expression of price drop risk - expected return rate - interest delta + exchange delta, that is, an optimum portfolio, is assumed. In this case, a coefficient, that is, a weight value, by which each variable in the expression (the price drop risk, the expected return rate, the interest delta, or the exchange delta) is multiplied, can be assumed to vary variously depending on portfolio investment policies and the like desired by the user.

20 [0096]

For example, when the price drop risk is considered important, a weight for the price drop risk:0.4, a weight for the expected return rate:0.2, a weight for the interest delta:0.2, and a weight for the exchange delta:0.2 are set. Note that, a total value of the weight values for the items is 1.

25 [0097]

In this case, as the local field g_j , an expression of the price drop risk - the expected return rate - the interest delta + the exchange delta of each portfolio for each investment policy, that is, pattern of weighting, is assumed.

30 [0098]

Additionally, σ^{jz} is considered to be a variable for affecting increase or decrease in the price of a predetermined

35

financial commodity with increase or decrease in the price of another financial commodity. The correlation strength of increase or decrease in the price between financial commodities, that is, the sensitivity, is expressed through the intervariable interaction J_{ij} .

[0099]

The intervariable interaction J_{ij} is specifically set through the considerations above, and a balanced point at which the holding ratio of financial commodities converges is identified through the ground state search for the Ising model expressed by Expression (3), that is, the above-described searching for the ground state in which the result of the expression of the price drop risk - the expected return rate - the interest delta + the exchange delta is the minimum. This holding ratio of financial commodities in the ground state is an optimum portfolio (a predetermined holding ratio of financial commodities forming the optimum portfolio) predicted for the pattern of weighting.

[0100]

---Data Structure Example---

Subsequently, various types of information used by the portfolio creation assistance device 100 of the present embodiment are described. Fig. 5 illustrates an example of the financial commodity information 125 in the present embodiment.

[0101]

The financial commodity information 125 of the present embodiment is a table in which information on various financial commodities is accumulated. As this information, the market sensitivity such as the expected return rate, the price drop risk, the interest delta, and the exchange delta, the commodity price (example: the stock index, the commodity futures prices, the foreign exchange rate, the foreign exchange forward rate, the long-short outstanding position ratio, the volatility of various indexes, the risk reversal, and the like), and various commissions (example: the buying and selling commission, the management

commission), and the like related to various financial commodities (example: the stocks, the futures instruments, the foreign exchanges, and the like) distributed by the financial information distribution system 300 may be included.

5 [0102]

The data structure thereof is, for example, a collection of records including data such as the expected return rate, the price drop risk, the interest delta, the exchange delta, the commodity price, and the commissions using the name of a financial
10 commodity as a key.

[0103]

Note that, the example of the financial commodity exemplified in the financial commodity information 125 in Fig. 5 is limited merely for convenience in description, and it is
15 assumed that there is stored information on other various financial commodities (the same applies below).

[0104]

Additionally, Fig. 6 illustrates an example of the weighting information 126 in the present embodiment. The
20 weighting information 126 of the present embodiment is a table in which information that defines a magnitude of the degree of importance of each of the items of the expected return rate, the price drop risk, the interest delta, and the exchange delta, assumed by the user in a financial institution or the like (one
25 who considers the improvement of a current portfolio) is accumulated. That is, it is information defining the weights for the above-described respective items corresponding to the properties (example: a balance is considered important, the expected return rate and the price drop risk are considered
30 important, or the expected return rate is considered important) of a portfolio as a target to be considered by a financial institution or the like.

[0105]

The data structure thereof is, for example, a collection
35 of records each including data on weight values for the respective

items corresponding to each portfolio property using identification information on the portfolio property as a key.

[0106]

---Flow Example---

5 Hereinafter, the practical procedure of a portfolio creation assistance method in the present embodiment is described with reference to the drawings. The various operations corresponding to the portfolio creation assistance method described below are implemented by a program read into a memory
10 or the like and executed by the portfolio creation assistance device 100. Note that, this program includes codes for operating the various operations described below.

[0107]

15 Fig. 7 is a diagram indicating a flow example of the portfolio creation assistance method in the present embodiment. Here, as an annealing machine, the portfolio creation assistance device 100 is assumed to calculate the ground state by using the above-described Ising model 1021 as a problem for a portfolio including, for example, three financial commodities (Figs. 8 and
20 9). Note that, the three financial commodities exemplified herein are issues "A" to "C" illustrated in Figs. 8 and 9.

[0108]

First, the portfolio creation assistance device 100 normalizes values of the respective variables (items) in the
25 above-described expression, "the price drop risk - the expected return rate - the interest delta + the exchange delta" (s10). The value normalized in this process is the value exemplified for each of the expected return rate, the price drop risk, the interest delta, and the exchange delta in Fig. 8.

30 [0109]

Specifically, the value of each variable is changed such that each value is within a range from 1 to 10 based on the maximum value and the minimum value of the variables among the financial commodities. In the example in Fig. 8, the maximum value of the
35 expected return rate is "20" of the issue "C", and the minimum

value is "5" of the issue "B".

[0110]

Accordingly, the portfolio creation assistance device 100 obtains a slope "0.6" and an intercept "-2" by solving an equation
 5 related to the maximum value, " $10 = 20a + b$ ", and an equation related to the minimum value, " $1 = 5a + b$ ", as simultaneous equations (see Fig. 10). Likewise, for the price drop risk, a slope "2.25" and an intercept "-1.25" are obtained (see Fig. 10). Likewise, for the interest delta, a slope "0.225" and an intercept
 10 "-1.25" are obtained (see Fig. 10). Likewise, for the exchange delta, a slope "0.12" and an intercept "-0.8" are obtained (see Fig. 10).

[0111]

In this case, the portfolio creation assistance device 100
 15 normalizes each variable of the above-described issues "A" to "C" based on each value of the slope and the intercept obtained for a corresponding variable as illustrated in Fig. 10, and thus the result in Fig. 11 is obtained. As illustrated in Fig. 11, the values of the variables all fall within the range from 1 to 10.

20 [0112]

Subsequently, the portfolio creation assistance device 100 automatically generates a combination of coefficients of the variables within a range in which the total of the coefficients for the above-described variables, that is, the weight values, is 1
 25 (s11). When the coefficient is "C", the above-described expression is expressed as $\text{Crisk} \cdot \text{price drop risk} - \text{Cear} \cdot \text{expected return rate} - \text{Cir} \cdot \text{interest delta} - \text{Cfx} \cdot \text{exchange delta}$.

[0113]

For example, when there is assumed the combination of
 30 coefficients with the number of variable being set to "5" by the rate of 10%, the number of the combinations is "1001" or the like.

[0114]

Subsequently, for a portfolio including the three financial commodities as described above, the portfolio creation assistance
 35 device 100, as an annealing machine, calculates the ground state

by using the Ising model 1021 of the number of the combinations of coefficients generated in s11 as a problem and estimates an optimum portfolio (s12). Such searching itself for the ground state is similar to the processing in the already-existing techniques.

[0115]

Fig. 12 shows the processing result from s12 described above, that is, the respective values of an objective function value (a value obtained from the expression: the price drop risk - the expected return rate - the interest delta + the exchange delta of each portfolio), the expected return rate, the price drop risk, the interest delta, and the exchange delta for each weight pattern. Note that, for the sake of simplifying the model, description herein is given of an example in which the weighting pattern for the variables of only the expected return rate, the price drop risk, and the interest delta out of variables is taken into consideration.

[0116]

Next, based on the processing result indicated in Fig. 12, that is, the respective values of the expected return rate, the price drop risk, and the market sensitivity of each portfolio, the portfolio creation assistance device 100 plots the position of each of portfolios on at least one plane from among the plane defined by the two axes of the price drop risk and the expected return rate (see Fig. 13), the plane defined by the two axes of the interest delta and the expected return rate (see Fig. 14), and the plane defined by the two axes of the expected return rate and the exchange delta (not illustrated), draws, in the plane on which the plotting is performed, an efficient frontier curve F_c corresponding to the plane, and outputs the plane to the user terminal 200 (s13).

[0117]

In this process, the portfolio creation assistance device 100 executes predetermined highlighting processing on portfolios X_p , out of the portfolios plotted on the plane defined by the two

axes of the price drop risk and the expected return rate (see Fig. 13), that have a lower price drop risk and a higher expected return rate than that of a current portfolio N_p of the user and that are plotted on a region above the efficient frontier curve F_c (in example in Fig. 13, the group of portfolios X_p is surrounded by a red circle).

[0118]

Additionally, as illustrated in Fig. 15, the portfolio creation assistance device 100 outputs the respective values of not only the expected return rate, the price drop risk, and the interest delta but also a risk asset, the number of issues to buy, the number of issues to sell, and a required cost of the above-described portfolios X_p to the user terminal 200 (s14).

[0119]

In this case, the portfolio creation assistance device 100 identifies financial commodities that make a difference between each of the above-described portfolios X_p and the current portfolio of the user, and calculates the number of financial commodities required to buy as the number of issues to buy and calculates the number of financial commodities required to sell as the number of issues to sell when changing the current portfolio to the portfolio X_p . Then, the portfolio creation assistance device 100 calculates a buying cost by multiplying the number of issues to buy by a unit price of the buying cost (various commissions and payment for commodity to be paid to a brokerage company and the like), for example. Additionally, the portfolio creation assistance device 100 calculates a selling cost by multiplying the number of issues to sell by a unit price of the selling cost (various commissions and losses to be paid to a brokerage company and the like). Eventually, the portfolio creation assistance device 100 calculates the required cost by combining the above-described buying cost and selling cost.

[0120]

On the other hand, the user can browse Figs. 13 to 15 described above through the user terminal 200, and, for example,

the user can select a desired portfolio from the portfolios included in the portfolios Xp with recognition of not only the indexes such as the expected return rate, the price drop risk, and the interest delta but also the cost for changing a portfolio and can use the desired portfolio as a candidate for a content of portfolio revision.

[0121]

Note that, for the portfolios Xp, the portfolio creation assistance device 100 of the present embodiment preferably arranges an object having an attribute according to the magnitude of the value of return on risk on the plane defined by the two axes of the interest delta and the exchange delta and outputs the plane to the user terminal 200 (Fig. 16).

[0122]

In this case, the portfolio creation assistance device 100 identifies a specific portfolio plotted on a region above the efficient frontier curve Fc out of the portfolios plotted on the plane defined by the two axes of the price drop risk and the expected return rate illustrated in Fig. 13 described above and calculates the value of return on risk by dividing the value of the expected return rate by the value of the price drop risk of the portfolio.

[0123]

For example, a value of the expected return rate of a portfolio "0.00025" is divided by a value of the price drop risk "0.00001", and thus a value of the value of return on risk "25" is calculated.

[0124]

Subsequently, for the specific portfolio, that is, the portfolio Xp, the portfolio creation assistance device 100 arranges an object having an attribute according to the magnitude of the value of return on risk on the plane defined by the two axes of the interest delta and the exchange delta and outputs the plane to the user terminal 200.

[0125]

As this object, a display object in a predetermined shape such as circle and rectangle can be assumed, for example. Additionally, its attribute is assumed to be a size, color, shape, pattern, pattern of blinking or flashing, and the like according to the magnitude of the value of return on risk. With this, it is possible to express a portfolio based on all the viewpoints of the expected return rate, the price drop risk, and the market sensitivity (the interest delta and the exchange delta), that is, in a four-dimensional event, and present the portfolio to the user while clearly distinguishing it among portfolios.

[0126]

So far, the best mode to implement the present invention and the like have been described specifically; however, the present invention is not limited thereto, and various changes can be made without departing from the gist thereof.

[0127]

According to the present embodiment described above, it is possible to efficiently generate multiple portfolio candidates based on the investment policies of each financial institution and present the portfolio candidates to a user in an easily understandable form.

[0128]

According to the descriptions herein, at least the followings are made explicit. To be specific, in the portfolio creation assistance device of the present embodiment, the computation unit may further execute processing of plotting the position of each of portfolios based on the values of the expected return rate, the price drop risk, and the market sensitivity of the portfolio concerned, on at least one plane from among the plane defined by the two axes of the price drop risk and the expected return rate, the plane defined by the two axes of the expected return rate and the interest delta as the market sensitivity, and the plane defined by the two axes of the expected return rate and the exchange delta as the market sensitivity, drawing, in the at least one plane on which the plotting is performed an efficient

frontier curve corresponding to the plane, and outputting the plane to a predetermined device.

[0129]

5 With this, the properties of each portfolio are clearly presented from multiple viewpoints, and the portfolio designing operation by a person in charge in a financial institution is effectively assisted. Consequently, it is possible to efficiently generate multiple portfolio candidates based on the investment policies of each financial institution and present the
10 portfolio candidates to a user in a more easily understandable form.

[0130]

Additionally, in the portfolio creation assistance device of the present embodiment, the computation unit may perform
15 predetermined highlighting processing on a portfolio out of the portfolios plotted on the plane defined by the two axes of the price drop risk and the expected return rate that is a portfolio having a lower price drop risk and a higher return than those of a current portfolio of a predetermined user and being plotted on
20 a region above the efficient frontier curve.

[0131]

With this, it is possible to clearly present a new portfolio from the current portfolio that can be expected to have an improvement in both the expected return rate and risk.
25 Consequently, it is possible to efficiently generate multiple portfolio candidates based on the investment policies of each financial institution and present the portfolio candidates to a user in a more easily understandable form.

[0132]

30 Moreover, in the portfolio creation assistance device of the present embodiment, the computation unit may further perform processing of identifying a specific portfolio plotted on a region above the efficient frontier curve out of the portfolios plotted on the plane defined by the two axes of the price drop risk and
35 the expected return rate and calculating a value of return on risk

by dividing a value of the expected return rate by a value of the price drop risk in the specific portfolio, and processing of, for the specific portfolio, arranging an object having an attribute according to the magnitude of the value of return on risk on the plane defined by the two axes of the interest delta and the exchange delta, and outputting the plane to the predetermined device.
[0133]

With this, it is possible to express a portfolio based on all the viewpoints of the expected return rate, the price drop risk, and the market sensitivity (the interest delta and the exchange delta), that is, in a four-dimensional event, and present the portfolio to the user. Consequently, it is possible to efficiently generate multiple portfolio candidates based on the investment policies of each financial institution and present the portfolio candidates to a user in a more easily understandable form.
[0134]

Furthermore, in the portfolio creation assistance device of the present embodiment the computation unit may further execute, during the computation, processing of normalizing the values of the respective items of the expected return rate, the price drop risk, and the market sensitivity of each of the financial commodities included in the portfolio indicated by the information such that each of the values falls within a predetermined defined range and setting the normalized values into the corresponding items in the predetermined expression.
[0135]

With this, it is possible to properly deal with a situation in which the ranges (scales of the number of digits) of the values of the respective items of the expected return rate, the price drop risk, and the market sensitivity are extremely different and make significant the expression as the Ising model. Consequently, it is possible to more efficiently generate multiple portfolio candidates based on the investment policies of each financial institution and present the portfolio candidates to a user in an

easily understandable form.

[0136]

Additionally, in the portfolio creation assistance device of the present embodiment, the computation unit may further
5 execute processing of applying buying and selling costs on which information is held in advance to financial commodities that make the difference between at least one of the portfolios and a current portfolio of a predetermined user to identify a cost required for portfolio change from the current portfolio and outputting
10 information on the cost to the predetermined device.

[0137]

With this, it is possible to present the information on the cost for changing the portfolio, and consequently, it is possible to efficiently generate multiple portfolio candidates based on
15 the investment policies of each financial institution and present the portfolio candidates to a user in a more easily understandable form.

[0138]

Moreover, the portfolio creation assistance device of the
20 present embodiment may be a CMOS annealing machine that solves a combinatorial optimization problem relating to the Ising model.

[0139]

With this, it is possible to recreate the operations of the Ising model in a pseudo manner by a circuit using an element such
25 as a CMOS (Complementary Metal Oxide Semiconductor) of a semiconductor and efficiently obtain a practical solution of the combinatorial optimization problem such as the creation of portfolio candidates for financial commodities under ambient temperature. Consequently, it is possible to more efficiently
30 generate multiple portfolio candidates based on the investment policies of each financial institution and present the portfolio candidates to a user in an easily understandable form.

[0140]

Furthermore, in the portfolio creation assistance method
35 of the present embodiment, the information processing device may

perform predetermined highlighting processing on a portfolio, out of the portfolios plotted on the plane defined by the two axes of the price drop risk and the expected return rate, that has a lower price drop risk and a higher expected return rate than that of a current portfolio of a predetermined user and that is plotted on a region above the efficient frontier curve.

[0141]

Additionally, in the portfolio creation assistance method of the present embodiment, the information processing device may further perform processing of identifying a specific portfolio plotted on a region above the efficient frontier curve out of the portfolios plotted on the plane defined by the two axes of the price drop risk and the expected return rate and calculating a value of return on risk by dividing a value of the expected return rate by a value of the price drop risk specific portfolio, and processing of, for the specific portfolio, arranging an object having an attribute according to the magnitude of the value of return on risk on the plane defined by the two axes of the interest delta and the exchange delta and outputting the plane to a predetermined device.

[0142]

Moreover, in the portfolio creation assistance method of the present embodiment the information processing device may further execute, during the computation, processing of normalizing the values of the respective items of the expected return rate, the price drop risk, and the market sensitivity of each of financial commodities included in the portfolio indicated by the information such that each of the values falls within a predetermined defined range and setting the normalized values into the corresponding items in the predetermined expression.

[0143]

Furthermore, in the portfolio creation assistance method of the present embodiment, the information processing device may further execute processing of applying buying and selling costs on which information is held in advance to financial commodities

that make the difference between at least one of the portfolios and a current portfolio of a predetermined user to identify a cost required for portfolio change from the current portfolio and outputting information on the cost to the predetermined device.

5 [0144]

Additionally, in the portfolio creation assistance method of the present embodiment, the information processing device may be a CMOS annealing machine that solves a combinatorial optimization problem relating to the Ising model.

10 [Reference Signs List]

[0145]

10 network

100 portfolio creation assistance device (annealing machine)

101 storage unit

15 102 program

1021 Ising model

103 memory

104 computation unit

105 communication unit

20 125 financial commodity information

126 weighting information

200 user terminal

300 financial information distribution system

[CLAIMS]

[Claim 1]

A portfolio creation assistance device, comprising:
a storage unit storing information on each of financial commodities; and
a computation unit performing a computation of an Ising model of a predetermined expression in which items of an expected return rate, a price drop risk, and a market sensitivity in a portfolio including combined predetermined ones of the financial commodities indicated by the information are combined with weights for the respective items, wherein
the computation unit outputs portfolios each obtained for one of patterns of the weights for the respective items as a result of the computation to a predetermined device, the portfolios each minimizing a value of the predetermined expression,
wherein the portfolio creation assistance device is a CMOS annealing machine that solves a combinatorial optimization problem relating to the Ising model.

[Claim 2]

The portfolio creation assistance device according to claim 1, wherein
the computation unit further executes
processing of plotting a position of each of the portfolios based on values of the expected return rate, the price drop risk, and the market sensitivity in the portfolio concerned, on at least one plane from among a plane defined by two axes of the price drop risk and the expected return rate, a plane defined by two axes of the expected return rate and an interest delta as the market sensitivity, and a plane defined by two axes of the expected return rate and an exchange delta as the market sensitivity, drawing, on the at least one plane on which the plotting is performed, an efficient frontier curve

corresponding to the plane, and outputting the plane to a predetermined device.

[Claim 3]

The portfolio creation assistance device according to claim 2, wherein

the computation unit performs

predetermined highlighting processing on a portfolio out of the portfolios plotted on the plane defined by the two axes of the price drop risk and the expected return rate, the portfolio having a lower price drop risk and a higher expected return rate than those of a current portfolio of a predetermined user and being plotted on a region above the efficient frontier curve.

[Claim 4]

The portfolio creation assistance device according to claim 3, wherein

the computation unit further performs

processing of identifying a specific portfolio plotted on a region above the efficient frontier curve out of the portfolios plotted on the plane defined by the two axes of the price drop risk and the expected return rate and calculating a value of return on risk by dividing a value of the expected return rate by a value of the price drop risk in the specific portfolio, and processing of, for the specific portfolio, arranging an object having an attribute according to a magnitude of the value of return on risk on the plane defined by the two axes of the interest delta and the exchange delta and outputting the plane to the predetermined device.

[Claim 5]

The portfolio creation assistance device according to claim 1, wherein

during the computation, the computation unit further

executes

processing of normalizing the values of the respective items of the expected return rate, the price drop risk, and the market sensitivity of each of the financial commodities included in the portfolio indicated by the information such that each of the values falls within a predetermined defined range and setting the normalized values into the corresponding items in the predetermined expression.

[Claim 6]

The portfolio creation assistance device according to claim 1, wherein

the computation unit further executes

processing of applying buying and selling costs on which information is held in advance to financial commodities that make a difference between at least one of the portfolios and a current portfolio of a predetermined user to identify a cost required for portfolio change from the current portfolio and outputting information on the cost to the predetermined device.

[Claim 7]

A portfolio creation assistance method, wherein

an information processing device including a storage unit storing information on each of financial commodities performs:

performing a computation of an Ising model of a predetermined expression in which items of an expected return rate, a price drop risk, and a market sensitivity in a portfolio including combined predetermined ones of the financial commodities indicated by the information are combined with weights for the respective items; and

outputting portfolios each obtained for one of patterns of the weights for the respective items as a result of the computation to a predetermined device, the portfolios each minimizing a value of the predetermined expression,

wherein the information processing device is a CMOS annealing machine that solves a combinatorial optimization problem relating to the Ising model.

[Claim 8]

The portfolio creation assistance method according to claim 7, wherein

the information processing device further executes processing of plotting a position of each of the portfolios based on values of the expected return rate, the price drop risk, and the market sensitivity in the portfolio concerned, on at least one plane from among a plane defined by two axes of the price drop risk and the expected return rate, a plane defined by two axes of the expected return rate and an interest delta as the market sensitivity, and a plane defined by two axes of the expected return rate and an exchange delta as the market sensitivity, drawing, on the at least one plane on which the plotting is performed, an efficient frontier curve corresponding to the plane, and outputting the plane to a predetermined device.

[Claim 9]

The portfolio creation assistance method according to claim 8, wherein

the information processing device performs predetermined highlighting processing on a portfolio out of the portfolios plotted on the plane defined by the two axes of the price drop risk and the expected return rate, the portfolio having a lower price drop risk and a higher expected return rate than those of a current portfolio of a predetermined user and being plotted on a region above the efficient frontier curve.

[Claim 10]

The portfolio creation assistance method according to

claim 9, wherein

the information processing device further performs processing of identifying a specific portfolio plotted on a region above the efficient frontier curve out of the portfolios plotted on the plane defined by the two axes of the price drop risk and the expected return rate and calculating a value of return on risk by dividing a value of the expected return rate by a value of the price drop risk in the specific portfolio, and processing of, for the specific portfolio, arranging an object having an attribute according to a magnitude of the value of return on risk on the plane defined by the two axes of the interest delta and the exchange delta and outputting the plane to the predetermined device.

[Claim 11]

The portfolio creation assistance method according to claim 7, wherein

during the computation, the information processing device further executes

processing of normalizing the values of the respective items of the expected return rate, the price drop risk, and the market sensitivity of each of the financial commodities included in the portfolio indicated by the information such that each of the values falls within a predetermined defined range and setting the normalized values into the corresponding items in the predetermined expression.

[Claim 12]

The portfolio creation assistance method according to claim 7, wherein

the information processing device further executes processing of applying buying and selling costs on which information is held in advance to financial commodities that make a difference between at least one of the portfolios and a current portfolio of a predetermined user to identify a cost

required for portfolio change from the current portfolio and outputting information on the cost to the predetermined device.