advancement of time not only to the potential coefficient but also to M, which indicates the number of most recent time-series data, seen from the time (t).

[0020]

A fifth aspect of the present invention is the method for detecting a change-point in time-series data, wherein the true market price at the time (t+1) is calculated by adding the potential term and a fluctuation error of the true market price at the time (t). Thereby, it is possible to precisely estimate the true market price at the time (t).

[0021]

A sixth aspect of the present invention is the method for detecting a change-point in time-series data, wherein the market price observed at the time (t) is the sum of the true market price at the time (t) and the observation error of the market price at the time (t). Thereby, it is possible to precisely estimate the degree of conformity of the true market price at the time (t) relative to the observed market price at the time (t).

[0022]

A seventh aspect of the present invention is the method for detecting a change-point in time-series data, wherein the fluctuation error of the true market price at the time (t) and the observation error of the market price at the time (t) are given by a probability density function in accordance with a normal distribution or the like. Thereby, it is possible to precisely estimate the true market price at the time (t) and the degree of conformity of the true market price at the time (t) relative to the observed market price at the time (t).

[0023]

An eighth aspect of the present invention is a method for predicting a probability density distribution of future time-series data values that calculates a true market price ~~P(t)~~P(t+N) ~~at the time (t)~~ at a time (t+N) by time advancement of the true market price P(t) at the time (t) based on a potential coefficient of the potential term at the time (t) calculated by the method for detecting a change-point in time-series data according to one of Claims 1 to 7, the value of M and a fluctuation error of the true market price at the time (t). Thereby, it is possible to predict the probability density distribution of future time-series data values using the PUCK model.

[0024]

A ninth aspect of the present invention is the method for predicting a probability density distribution of future time-series data values, wherein when a total number of particles is Np, a number specifying the particle is j (where j is an integer satisfying $1 \leq j \leq Np$), a potential coefficient of the particle with the number j at the time (t) is $b^{(j)}_i(t)$ (where i is an integer of 2 or more indicating an order of a potential), a fluctuation error of the true market price of the particle

degree of conformity of the true market price at the time (t) relative to the observed market price at the time (t).

[0031]

An sixteenth aspect of the present invention is the program for detecting a change-point in time-series data, wherein in the program for detecting the change-point in the time-series data, the market price observed at the time (t) is the sum of the true market price at the time (t) and the observation error of the market price at the time (t). Thereby, it is possible to precisely estimate the degree of conformity of the true market price at the time (t) relative to the observed market price at the time (t).

[0032]

A seventeenth aspect of the present invention is the program for detecting a change-point in time-series data, wherein the fluctuation error of the true market price at the time (t) and the observation error of the market price at the time (t) are given by a probability density function in accordance with a normal distribution or the like. Thereby, it is possible to precisely estimate the true market price at the time (t) and the degree of conformity of the true market price at the time (t) relative to the observed market price at the time (t).

[0033]

An eighteenth aspect of the present invention is a program for predicting a probability density distribution of future time-series data values, wherein a true market price ~~P(t)~~P(t+N) ~~at the time (t)~~ at a time (t+N) is calculated by time advancement of the true market price P(t) at the time (t) based on a potential coefficient of the potential term at the time (t) calculated by the program for detecting a change-point in time-series data according to one of Claims 11 to 17, the value of M and a fluctuation error of the true market price at the time (t). Thereby, it is possible to predict the probability density distribution of future time-series data values using the PUCK model.

[0034]

An nineteenth aspect of the present invention is the program for predicting a probability density distribution of future time-series data values, wherein when a total number of particles is Np, a number specifying the particle is j (where j is an integer satisfying $1 \leq j \leq Np$), a potential coefficient of the particle with the number j at the time (t) is $b^{(j)}{}_i(t)$ (where i is an integer of 2 or more indicating an order of a potential), a fluctuation error of the true market price of the particle with the number j at the time (t) is $f^{(j)}{}_P(t)$, the true market price of the particle with the number j at the time (t) is $P^{(j)}(t)$, the true market price of the particle with the number j at the time (t+N) is $P^{(j)}(t+N)$, a core price of the market price of the particle with the number j at the time (t)

In this embodiment, as described above, a uniform distribution is introduced in order to give consideration to a sudden event in which there is a steep change to the time-series data. In other words, in case of no uniform distribution, particles with a lower degree of conformity are culled and eliminated each time the particles advance a generation. When a sudden event occurs in such a state, particles that conform to the sudden event will have already been eliminated, and the sudden event cannot be tracked. However, in this embodiment, the introduction of a uniform distribution taking into account a sudden event makes it possible to prevent the elimination of particles with a low degree of conformity. It is thereby possible to retain particles with a high degree of conformity to the sudden event, and to increase the ability to track the sudden event compared to an ordinary particle filter method. In this manner, the introduction of the uniform distribution makes it possible to achieve a specific effect that cannot be achieved when an ordinary normal distribution or Lorentz distribution is used.

[0066]

Next, a description will be provided for the number M(t) of most recent data. Similar to the potential coefficient b(t) at time (t), a uniform distribution is also introduced to the number M(t) of most recent data, in order to given consideration to a sudden event. In this embodiment, the number M(t) of most recent data is represented as a mixed distribution of a uniform distribution and a probability density function at time (t-1). The number M(t) of most recent data is processed in the step S1 described above. FIG. 5 is a flow chart illustrating a method for determining the number M(t) of most recent data at time (t) in the first embodiment. In such a case, the number M(t) of most recent data is represented by the Equation (29).

[Equation31]

$$M(t) \sim (1 - M_{mut}) G(M(t) \mid M(t-1), \sigma_M, M_{\max}, M_{\min}) + M_{mut} U(M_{\min}, M_{\max}) \quad \cdots \quad (29)$$

[0067]

Herein, similar to the case of the potential coefficient b(t) at time (t), a random number u is generated (step S21 of FIG. 5) and the random number u is compared with M_{mut} (step S22 of FIG. 5), whereby the mixture ratio of the uniform distribution and the probability density function at time (t-1) is determined.

[0068]

That is, when $u \geq M_{mut}$, the number M(t) of most recent data is established from only the probability density function at time (t-1) (step S23 of FIG. 5). Accordingly, the number M(t) of most recent data in such a case is represented by the upper equation of the following Equation (30).

[Equation 32]

$$M_{t|t-1}^{(j)}(t) \sim G\left(\mid M_{t-1|t-1}^{(j)}, r, M_{max}, M_{min} \right)$$

$$M_{t|t-1}^{(j)}(t) \sim U(M_{min}, M_{max}) \quad \cdots \quad (30)$$

where $U(M_{min}, M_{max})$ is a uniform probability density function such that the lower limit is an integer value M_{min}, and the upper limit is an integer value M_{max}.

[0069]

On the other hand, when $u < M_{mut}$, the number M(t) of most recent data is established only from the uniform distribution (step S24 of FIG. 5). Accordingly, the number M(t) of most recent data is represented by the lower equation of the ~~Equation (31)~~(30).

[0070]

The following illustrates a specific example of the expected probability density function G(·). When $M_{min} < M(t-1) < M_{max}$, the probability density function G(·) is represented by the following Equation (31).

[Equation 33]

$$G(M(t-1)+1 \mid M(t-1), r, M_{min}, M_{max}) = r$$
$$G(M(t-1) \mid M(t-1), r, M_{min}, M_{max}) = 1-2r$$
$$G(M(t-1)-1 \mid M(t-1), r, M_{min}, M_{max}) = r \quad \cdots \quad (31)$$

where $0 < r < 1$.

In the boundary conditions, the probability density function G(·) is represented by the following Equation (32).

[Equation 34]

$$G(M_{max}-1 \mid M_{max}, r, M_{min}, M_{max}) = r$$
$$G(M_{max} \mid M_{max}, r, M_{min}, M_{max}) = 1-r$$
$$G(M_{min}+1 \mid M_{min}, r, M_{min}, M_{max}) = r$$
$$G(M_{min} \mid M_{min}, r, M_{min}, M_{max}) = 1-r \quad \cdots \quad (32)$$

For M(t-1) outside the range given above, the probability density function G(·) is represented by the following Equation (33).

[Equation 35]

$$G\left(\mid M(t-1), r, M_{min}, M_{max} \right) = 0 \quad \cdots \quad (33)$$

[0103]

The computation unit 2a reads in, from the memory unit 1 via the bus 4, the parameters and time-series data calculated by the program 20, and the program 40. The computation unit 22a executes the read-in program 40 and performs prediction of the probability density distribution of values of future time-series data. The program 40 includes a parameter reading unit 41, a data reading unit 42, a calculating unit 43 and a count unit 44.

[0104]

Specifically, the parameter reading unit 41 reads in the parameters $(b^{(j)}{}_i(t), M^{(j)}(t), f^{(j)}{}_P(t))$ of the j-th particle at time (t) calculated by the program 20. In other words, the parameter reading unit 41 performs processing corresponding to the step S31 of FIG. 7. Note that the parameters of the particle at time (t) calculated by the program 20 is stored in the memory unit 1, for example, and read by the parameter reading unit 41 according to need.

[0105]

The data reading unit 42 reads in the true market price $P^{(j)}(t)$ at time (t) calculated by the program 20. In other words, the data reading unit 42 performs processing corresponding to the step S32 of FIG. 7. Note that the true market price $P^{(j)}(t)$ at time (t) calculated by the program 20 is stored in the memory unit 1, for example, and read by the data reading unit 42 according to need.

[0106]

The calculating unit 43 performs processing corresponding to the step S33 of FIG. 7. Specifically, the calculating unit 43 calculates the market price after one tick from the set time using the Equation (36).

[0107]

The count unit 44 performs processing corresponding to the steps S34 and S35 of FIG. 7. Specifically, the count unit 44 determines whether the time of the most recent processing is the final step (t=t+N) (the processing in the step S34 of FIG. 7). When the time of the most recent processing is not the final step (t=t+N), the time (t) advances by one step, and the processing returns to the calculating unit 43. The calculation of the Equation (36) is thereby repeated and, when it reaches the time (t+N), the same calculation as represented by the Equation (37) can be obtained. On the other hand, when the time of the most recent processing is the final step (t=t+N), the processing is terminated, and the probability density distribution of the market price at time (t+N) is output to the display unit 3 based on the calculation result.

[0108]

The display unit 3 displays the probability density distribution of the market price at time (t+N) output from the computation unit 22a, on a liquid crystal display screen for example, in a visible state. At such a time, the probability density function of the market price from time (t) to time (t+N) may be sequentially displayed on the display device.

[0109]

As described above, according to this embodiment, the predication program and the prediction device for predicting the probability density distribution of values of future time-series data according to the fourth embodiment can be implemented in a specific manner.

[0110]

Fifth Embodiment

A description of another method for predicting a probability density distribution of values of future time-series data according to a fifth embodiment of the present invention will now be provided. In the third embodiment, it is described that values of the future market price can be obtained as the probability density distribution by the advancement of time of the PUCK model. Specifically, the advancement of time is performed using the potential coefficient b(t) at time (t), which is the starting point of the time advancement. Note that, in this embodiment, the order i of the potential and the number j of the particle are not illustrated.

[0111]

In the third embodiment, the future is predicted on the assumption that the value of the potential coefficient b(t) at time (t) is the same during the period of the future time (t+1) to (t+N). Accordingly, in the third embodiment, it is only possible to predict the changes over time of short-term price fluctuations. On the other hand, if an equation for the time advancement of the potential coefficient b(t) can be obtained as described in this embodiment, the changes of the potential coefficient b(t) from the future time (t+1) to (t+N) can be predicted. This enables the obtainment of the more accurate price distribution at future time (t+N). It is therefore important to estimate an equation for the time advancement of the potential coefficient b(t) when predicting the changes over time of long-term price fluctuations. For example, the relationship of the potential coefficient b(t+1) at time (t+1) with the potential coefficient b(t) at time (t) is defined by the following Equation (38).

[Equation 40]

$$b(t+1)-b(t)=-\frac{\partial}{\partial b}G(b)\Big|_{b=b(t)}+f_b(t) \qquad \cdots \qquad (38)$$

changes in trends that cannot be expressed by a secondary potential. Therefore, the potential U(q, t) at time (t) is not limited to being secondary, but rather can be introduced in the form of a function including a higher-order potential term, and the coefficient of the higher-order potential term can be estimated to follow the sudden changes in trends. In particular, the introduction of a tertiary potential makes it possible to track a boom or collapse in a financial market more rapidly than with a secondary potential. It is also possible to further analyze the directionality of such a boom (that is, upward trend) or collapse (that is, downward trend).

[0125]

Also, estimating a simultaneous potential distribution or the like of b(t) and M(t) at time (t) using the secondary potential model makes it possible to estimate a different dealer strategy for plural time scales (a multi-scale PUCK model). Further, estimating a third- and higher-order potential coefficient allows for the visualization of strategies for dealers following trends and of collective behavior causing one-sided fluctuations in pricing (the prospect of a multi-scale PUCK model including a higher-order potential).

[0126]

This application is based upon and claims the benefit of priority from Japanese patent application No. 2011-196512 filed on September 8, 2011 and Japanese patent application No. 2012-50819 filed on March 7, 2012, the disclosure of which is incorporated herein in its entirety by reference.

Industrial Applicability

[0127]

The present invention is applicable to analysis or prediction of fluctuations over time in the market price in exchange markets and stock markets, or analysis or prediction of fluctuations over time in other time-series data such as management or measurement data.

Reference Signs List

[0128]

1 STORAGE UNIT

2, 2a COMPUTATION UNIT

3 DISPLAY UNIT

4 BUS

20, 40, 60 PROGRAM

21 INITIAL SETTING UNIT

22 PDF GENERATION UNIT

23 DEGREE OF CONFORMITY EVALUATION UNI

in the first step, the PUCK model parameters of a later time than the group of particles having parameters representing the state of the PUCK model are updated.

4. The method for detecting a change-point in time-series data according to any one of Claims 1 to 3, wherein:

in the third step,

a random number is generated for each of the particles, and

the random number is compared with the first predetermined value, where

a conditional probability density function for assuming M at the time (t) is generated as particles when the random number is greater than the first predetermined value, and

a probability density function comprising a uniform distribution is generated as particles when the random number is less than the first predetermined value.

5. The method for detecting a change-point in time-series data according to any one of Claims 1 to 4, wherein:

the true market price at the time (t+1) is calculated by adding the potential term and a fluctuation error of the true market price at the time (t).

6. The method for detecting a change-point in time-series data according to any of Claims 1 to 5, wherein:

the market price observed at the time (t) is the sum of the true market price at the time (t) and the observation error of the market price at the time (t).

7. The method for detecting a change-point in time-series data according to Claim 5 or 6, wherein:

the fluctuation error of the true market price at the time (t) and the observation error of the market price at the time (t) are given by a probability density function in accordance with a normal distribution.

8. A method for predicting a probability density distribution of future time-series data values, comprising:

calculating a true market price ~~P(t)~~P(t+N) ~~at the time (t)~~ at a time (t+N) by time advancement of the true market price P(t) at the time (t) based on a potential coefficient of the potential term at the time (t) calculated by the method for detecting a change-point in time-series data according

14. The program for detecting a change-point in time-series data according to any one of Claims 11 to 13, wherein:

in the first step,

processing for generating a random number,

processing for generating a conditional probability density function assuming a parameter of the PUCK model at the time (t) as particles, and

processing for generating a probability density function comprising a uniform distribution as particles when the random number is less than the first predetermined value

are executed.

15. The program for detecting a change-point in time-series data according to any one of Claims 11 to 14, wherein:

the true market price at the time (t) is calculated by adding the potential term and the fluctuation error of the true market price at the time (t).

16. The method for detecting a change-point in time-series data according to any one of Claims 11 to 15, wherein:

the market price observed at the time (t) is the sum of the true market price at the time (t) and the observation error of the market price at the time (t).

17. The program for detecting a change-point in time-series data according to Claim 15 or 16, wherein:

the fluctuation error of the true market price at the time (t) and the observation error of the market price at the time (t) are given by a probability density function in accordance with a normal distribution.

18. A program for predicting a probability density distribution of future time-series data values, wherein:

a true market price ~~P(t)~~P(t+N) ~~at the time (t)~~ at a time (t+N) is calculated by time advancement of the true market price P(t) at the time (t) based on a potential coefficient of the potential term at the time (t) calculated by the program for detecting a change-point in time-series data according to one of Claims 11 to 17, the value of M and a fluctuation error of the true market price at the time (t).