SPECIFICATION

TITLE OF INVENTION:
NAVIGATIONAL ANALYSIS DEVICE, NAVIGATIONAL ANALYSIS METHOD, PROGRAM, AND RECORDING MEDIUM

TECHNICAL FIELD

[0001] The present invention relates to a technique for analyzing fuel consumption in navigation of a ship.

BACKGROUND ART

[0002] Navigation of ships is affected by various factors such as weather and oceanographic phenomena. Therefore, ships cannot always sail as planned. The ships may sail a route deviated from a planned route, or may accelerate or decelerate temporarily (or be anchored by waiting offshore). When the ships do not sail as planned, a variation may occur in a fuel required for a single navigation. If a cause of an increase or a decrease in an amount of fuel consumption can be determined when the amount of fuel consumption increases or decreases from an estimated amount, it may help in making the navigation plan of subsequent navigation.

[0003] Patent Document 1 discloses, for the purpose of analyzing, with respect to a device such as a vehicle, a cause of a difference between fuel costs to be compared, a technique for calculating a degree of influence of various factors on a fuel cost incurred during a predetermined period in terms of expenditure, and also calculating, by replacing a value of any one of the various factors during a comparative period, a difference between fuel costs before and after the replacement. In Patent Document 1, the factors contributing to fuel cost are assumed to be a fuel consumption rate, a unit cost of fuel, and a distance sailed.

PRIOR ART DOCUMENT

PATENT DOCUMENT

[0004] Patent Document 1: JP2010-267184A (paragraph 0035, etc.)

SUMMARY OF THE INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

[0005] Although the technique disclosed in patent Document 1 allows the

understanding of a degree of influence of each factor on fuel cost during a comparative period, it is impossible to understand a cause of fluctuation in fuel consumption itself.

In contrast, it is an object of the present invention to allow the understanding of a particular element in the factors contributes to a fluctuation in an amount of fuel consumption.

MEANS FOR SOLVING THE PROBLEM

[0006] In the present invention, there is provided a navigational analysis device including: a first acquisition means that acquires navigation data indicative of both an amount of fuel consumption in navigation of a ship and at least two elements contributing to a variation in the amount of fuel consumption in the navigation; a second acquisition means that acquires reference data indicative of a reference amount of fuel consumption; a calculation means that calculates, based on the navigation data and the reference data, a fluctuation caused by at least one element of the at least two elements, the fluctuation being included in a fluctuation in the amount of fuel consumption indicated by the navigation data with respect to the reference amount of fuel consumption; and an output means that outputs a calculation made by the calculation means.

[0007] In the navigational analysis device according to the present invention, the reference data may include data indicative of a relationship between the reference amount of the fuel consumption and at least two reference elements that contribute to a variation in the reference amount of fuel consumption; and the calculation means may calculate, based on a difference between the reference amount of fuel consumption and an amount of fuel consumption that is obtained based on the reference data by using the navigation data as a value of a first element of the at least two elements, and by using the reference element as a value of a second element, a fluctuation caused by the first element.

Also, in the navigational analysis device according to the present invention, the calculation means may calculate the fluctuation by using each of values of the at least two elements as the first element.

Further, in the navigational analysis device according to the present invention,

the reference data may include a plurality of sets of data indicative of a relationship between an actual measured value of an amount of fuel consumption measured in another navigation of the navigation and the at least two reference elements; and the calculation means may determine the reference amount of fuel consumption by using a plurality of actual measured values of amounts of fuel consumption included in the reference data.

Further, in the navigational analysis device according to the present invention, the calculation means may determine the reference amount of fuel consumption based on a result of a regression analysis, the regression analysis being performed by using data that satisfies a specific weather condition among a plurality of sets of data indicative of a relationship between an actual measured value of an amount of fuel consumption included in the reference data and the at least two reference elements.

Further, in the navigational analysis device according to the present invention, the first acquisition means may acquire prediction data indicative of both a predictive value of an amount of fuel consumption in navigation of the ship and a predictive value of the element; and the calculation means may calculate, based on the prediction data and the reference data, a fluctuation caused by at least one element of the at least two elements, the fluctuation being included in a fluctuation in the amount of fuel consumption indicated by the prediction data with respect to the reference amount of fuel consumption.

Further, in the navigational analysis device according to the present invention, the second acquisition means may acquire, as the reference data, prediction data indicative of both a predictive value of an amount of fuel consumption in navigation of the ship and a predictive value of the element.

Further, in the navigational analysis device according to the present invention, the element may be an element relating to at least one of a distance sailed, a ship speed, weather, and an oceanographic phenomenon.

[0008] Also, in the present invention, there is provided a navigational analysis method including: a first step of acquiring navigation data indicative of both an amount of fuel consumption in navigation of a ship and at least two elements contributing to a variation in the amount of fuel consumption in the navigation; a second step of

acquiring reference data indicative of a reference amount of fuel consumption; a third step of calculating, based on the navigation data and the reference data, a fluctuation caused by at least one element of the at least two elements, the fluctuation being included in a fluctuation in the amount of fuel consumption indicated by the navigation data with respect to the reference amount of fuel consumption; and a fourth step of outputting a calculation made in the third step.

[0009] Further, in the present invention, there is provided a program for causing a computer to execute: a first step of acquiring navigation data indicative of both an amount of fuel consumption in navigation of a ship and at least two elements contributing to a variation in the amount of fuel consumption in the navigation; a second step of acquiring reference data indicative of a reference amount of fuel consumption; a third step of calculating, based on the navigation data and the reference data, a fluctuation caused by at least one element of the at least two elements, the fluctuation being included in a fluctuation in the amount of fuel consumption indicated by the navigation data with respect to the reference amount of fuel consumption; and a fourth step of outputting a calculation made in the third step.

[0010] Further, in the present invention, there is provided a computer-readable recording medium storing a program for causing a computer to execute: a first step of acquiring navigation data indicative of both an amount of fuel consumption in navigation of a ship and at least two elements contributing to a variation in the amount of fuel consumption in the navigation; a second step of acquiring reference data indicative of a reference amount of fuel consumption; a third step of calculating, based on the navigation data and the reference data, a fluctuation caused by at least one element of the at least two elements, the fluctuation being included in a fluctuation in the amount of fuel consumption indicated by the navigation data with respect to the reference amount of fuel consumption; and a fourth step of outputting a calculation made in the third step.

EFFECTS OF THE INVENTION

[0011] According to the present invention, it is possible to understand a particular element in the factors contributes to a fluctuation in an amount of fuel consumption.

BRIEF EXPLANATION OF THE DRAWINGS

[0012] [Fig. 1] A diagram showing an overall configuration of navigational analysis system (10).

[Fig. 2] A block diagram showing a hardware configuration of analysis device (500).

[Fig. 3] A block diagram showing a functional configuration of control unit (510).

[Fig. 4] A flowchart showing a process performed by analysis device (500).

[Fig. 5] A conceptual diagram showing a breakdown of an amount of fuel consumption.

[Fig. 6] A diagram showing a method of calculating a reference amount of fuel consumption.

[Fig. 7] A diagram explaining a method of calculating a fluctuation in an amount of fuel consumption caused by an average ship speed.

[Fig. 8] A diagram explaining a method of calculating a fluctuation in an amount of fuel consumption caused by weather.

[Fig. 9] A diagram showing an example of an analysis report.

[Fig. 10] A diagram showing an example of a method of displaying a breakdown of fuel consumption elements.

[Fig. 11] A diagram showing an example of another method of displaying a breakdown of fuel consumption elements.

MODES FOR CARRYING OUT THE INVENTION

[0013] [Exemplary Embodiment]

Fig. 1 is a diagram showing an overall configuration of navigational analysis system (10) according to an embodiment of the present invention. Navigational analysis system (10) is a system for analyzing information on an amount of fuel consumption in navigation of a ship, and for informing a user of a cause of a fluctuation (an increment or a decrement) in the amount of fuel consumption. Navigational analysis system (10) includes communication device (100), network (200), navigation information DB (database) (300), weather information DB (400), and analysis device (500).

[0014] Communication device (100) is a device for transmitting navigation information of a ship. Communication device (100) may be installed in the ship, and may

transmit navigation information acquired on the ship via satellite communications. Alternatively, communication device (100) may acquire information, on land after navigation, from a recording medium in which navigation information that is acquired on the ship is recorded, and may read and transmit the navigation information.

[0015] The navigation information as used herein refers to information on navigation from a departure point to a destination. The navigation information includes at least data indicative of an amount of fuel consumption and data indicative of an element contributing to a variation in the amount of fuel consumption (hereinafter referred to as a "fuel consumption element"). For example, the navigation information includes data in which an arrival date and time at port, a departure date and time at port, an average ship speed, a distance sailed, an amount of fuel consumption, etc. are recorded. The navigation information may be data provided directly from a measuring device that is installed in the ship. Alternatively, a person may input navigation information using an input unit (a keyboard, etc.) by reading a value indicated by the measuring device that is installed in the ship.

[0016] Network (200) is a communication network for implementing communications between devices. Network (200) consists of the Internet and a mobile communication network. For example, when communication device (100) is installed in the ship, network (200) includes a network for performing wireless communications via a communication satellite (satellite communications).

[0017] Navigation information DB (300) is a database in which the navigation information is recorded. Navigation information DB (300) is configured to cumulatively record the navigation information obtained from a plurality of ships to be analyzed, and to retrieve the navigation information as required. Navigation information DB (300) stores, not only the navigation information on the same route having a common departure point and destination, but also navigation information on a different departure point or destination. It is to be noted that navigation information DB (300) does not have to be configured independently of other components. Navigation information DB (300) may be a part of analysis device (500).

[0018] Weather information DB (400) is a database in which weather information is recorded. The weather information as used herein refers to information on weather forecast of various places. For example, the weather information includes data in which forecast values of weather, wind power (or a wind speed), a wind direction, etc. are recorded together with a date and time for which the forecast is made. The weather information includes at least information on the weather forecast on a route of the ship. The weather information as used herein may include information on oceanographic phenomena (an ocean current, a tidal current, a wave height, etc.).

[0019] Analysis device (500) is a device for analyzing navigation information. Analysis device (500) retrieves the required navigation information from navigation information DB (300), analyzes the navigation information, and outputs a report according to an analysis (hereinafter referred to as an "analysis report") in response to an operation of a user. The analysis report includes at least the analysis of the navigation information. The analysis report may include, in addition to the analysis, a trend graph of data such as a ship speed or a rate of fuel consumption (hereinafter referred to as a "fuel consumption rate"), summary information of the entire navigation, and a weather chart.

[0020] Fig. 2 is a block diagram showing a hardware configuration of analysis device (500). Analysis device (500) includes control unit (510), storage unit (520), communication unit (530), operation input unit (540), and display unit (550). For example, analysis device (500) may be implemented by a personal computer that is able to execute a dedicated application program.

[0021] Control unit (510) is a main means for analyzing navigation information. Control unit (510) includes an arithmetic processing device such as a CPU (Central Processing Unit) and a memory. Control unit (510) acquires data required for the analysis of navigation information, and outputs data used for displaying the analysis report after analyzing the navigation information, by executing a predetermined program to control an operation of each unit of analysis device (500).

[0022] Storage unit (520) is a means for storing data. Storage unit (520) includes a recording medium such as a hard disk or a flash memory. Storage unit (520) stores data used by control unit (510). For example, storage unit (520) may store a

program to be executed by control unit (510), and planning information, which is described later.

[0023] Communication unit (530) is a means for transmitting data to or receiving data from another external device of analysis device (500). Communication unit (530) receives data from communication device (100), navigation information DB (300), and weather information DB (400) in response to an instruction provided by control unit (510). Communication unit (530) receives the data via network (200).

[0024] Operation input unit (540) is a means for receiving an input from an operation of a user. Operation input unit (540) may receive an operation using a mouse and a keyboard, or may receive an operation using a touch screen. Operation input unit (540) provides control unit (510) with operation information indicating the operation of the user.

[0025] Display unit (550) is a means for displaying information. Display unit (550) includes a display device such as a liquid crystal display. Display unit (550) displays information (such as the analysis report) according to the display data provided by control unit (510). It is to be noted that display unit (550) may be configured, without including the display device, as a means for providing a display device that is located in a remote place (or a computer device including the display device) with the display data to cause the display device to display information (namely, a means for controlling the display of a display means).

[0026] Fig. 3 is a block diagram showing a functional configuration regarding the analysis of the navigation information in control unit (510). Control unit (510) implements first acquisition means (511), second acquisition means (512), calculation means (513), and output means (514), by executing the predetermined program to cooperate with other units of analysis device (500).

[0027] First acquisition means (511) is a means for acquiring navigation data measured in navigation to be analyzed. The navigation data is included in the navigation information stored in navigation information DB (300). The navigation data includes data indicative of both an actual measured value of an amount of fuel consumption in the navigation to be analyzed, and an actual measured value of the fuel consumption elements. The fuel consumption elements as used herein refer to

elements regarding a distance sailed by a ship, a ship speed, weather during navigation, etc.

[0028] For example, in general, if the distance sailed by the ship is longer, an amount of fuel consumption increases (although, if another fuel consumption element such as the ship speed varies the amount of fuel consumption does not always increase). However, the ship does not always sail through a planned route. For example, the ship may make a detour from a planned route to avoid a low pressure area. In this case, a greater amount of fuel will be consumed than an estimated amount of fuel consumption.

[0029] Also, in general, if the ship speed decreases, the amount of fuel also decreases. Additionally, in the navigation of the ship, if the ship sails at a constant speed (namely, a variation of the ship speed is small), the amount of fuel consumption decreases. Therefore, from the viewpoint of the ship speed, it will be desirable that the ship sails at a constant speed as far as possible, without accelerating or decelerating during a predetermined period, and that the ship arrives at a destination without waiting offshore. However, depending on a ship's navigator, an action may be taken to arrive in the vicinity of the destination earlier than planned to prepare for any contingency.

[0030] It is to be noted that the actual measured value of the ship speed is assumed to be a value that is measured at predetermined time intervals in the navigation to be analyzed. The actual measured value allows the understanding of both an average speed of the ship per a single navigation and a fluctuation in the ship speed (an allocation of the ship speed). For example, the actual measured value is measured every hour. However, when the ship sails on a long-distance route, the actual measured value may be measured at intervals of a time longer than an hour (every half day, or daily).

[0031] Further, one of the elements having a relatively large influence on the amount of fuel consumption among the weather during navigation is wind. For example, as an actual measured value of the wind, a numerical value indicated by the Beaufort wind force scale (Beaufort scale) can be used. It is assumed that the actual measured value of the weather is measured at predetermined time intervals in

navigation to be analyzed, similar to the actual measured value of the ship speed.

[0032] It is to be noted that the navigation data may include another measured value that allows the determination of an actual amount of fuel consumption or fuel consumption element, instead of the actual measured value itself of the amount of fuel consumption or fuel consumption element. In other words, the data indicative of the actual measured value can be regarded as data that allows the determination of the actual measured value. For example, the navigation data includes both an actual measured value of a load of the main engine and an actual measured value of a navigation time, instead of the amount of fuel consumption itself, and allows the determination of the amount of fuel consumption by a predetermined calculation. Alternatively, it is possible to acquire a measured value of a number of rotations of the main engine instead of the ship speed, and to calculate the ship speed from the number of rotations of the main engine by a predetermined calculation.

[0033] Second acquisition means (512) is a means for acquiring reference data to be compared with the navigation data. The reference data includes data indicative of a reference value of an amount of fuel consumption (a reference amount of fuel consumption). In this embodiment, it is assumed that the reference data is a set of the navigation data that is measured in another navigation having the same route (a departure point and destination) as the navigation indicated by the navigation data, namely, navigation to be analyzed, and that the reference data is retrieved from navigation information DB (300). For example, when the navigation as used herein is navigation on a regular route, the reference data includes navigation data that is measured in past navigation on this route.

[0034] Calculation means (513) is a means for comparing the navigation data acquired by first acquisition means (511) and the reference data acquired by the second acquisition means (512). Calculating means (513) calculates, based on the navigation data and the reference data, a fluctuation caused by each of the fuel consumption elements among a fluctuation in the actual measured value with respect to the reference amount of fuel consumption. In other words, calculating means (513) calculates a degree of contribution of each of the fuel consumption elements to the fluctuation in the amount of fuel consumption. Calculating means (513) is also

able to determine the reference amount of fuel consumption on the basis of the reference data, as described later. The determination of the reference amount of fuel consumption can be implemented by a regression analysis using the reference data.

[0035] Output means (514) is a means for outputting a calculation made by the calculation means (513). In this embodiment, output means (514) provides display unit (550) with display data indicative of the calculation made by the calculation means (513). The display data generated by output means (514) includes at least data used for displaying an analysis report. It is to be noted that output means (514) may acquire, as necessary, data other than the calculation made by calculating means (513) according to contents of the analysis report.

[0036] The configuration of Navigational analysis system (10) is as described above. A user (e.g., a ship's navigator on board or a ship operation manager on shore) can instruct to generate the analysis report using navigational analysis system (10). For example, the user can acquire, by designating navigation to be analyzed, an analysis report on this navigation.

[0037] Fig. 4 is a flowchart showing a process executed by analysis device (500). Control unit (510) of analysis device (500) firstly receives an instruction to generate an analysis report (step S1). Controller (510) is able to receive an input from an operation of a user by acquiring operation information from operation input unit (540). The user can designate navigation by using a departure point, a destination, a date and time, or a name of a ship or route. The user also can search for and find the navigation to be analyzed by using navigation information DB (300). The user may designate one or more fuel consumption elements to be displayed in the analysis report.

[0038] Upon receiving the instruction to generate the analysis report, control unit (510) acquires the required data. Control unit (510) identifies the navigation designated by the user, and acquires, from navigation information DB (300), navigation data measured in the identified navigation (step S2). Control unit (510) further identifies other navigation information to be compared with the acquired navigation data, and acquires the identified other navigation information from navigation

information DB (300) to use the same as reference data (step S3). It is to be noted that although steps S2 and S3 are shown separately in Fig. 4, control unit (510) may acquire the navigation data and the reference data simultaneously.

[0039] Control unit (510) then calculates a difference between an actual measured value and a reference value of an amount of fuel consumption in the navigation to be analyzed, and calculate a fluctuation in each of the fuel consumption elements on the basis of the difference (namely, the increment or decrement) (step S4). Control unit (510) then generates display data including the calculation of step S4, and displays an analysis report according to the display data by providing display unit (550) with the display data (step S5).

[0040] The outline of the process by analysis device (500) is as described above. The specific method of the analysis of the navigation data executed by analysis device (500) will be described below in more detail by citing an example. It is to be noted that in the following example it is assumed that the navigation to be analyzed is a regular line, and there is comparable past navigation information.

[0041] Fig. 5 is a conceptual diagram showing a breakdown of the amount of fuel consumption. In Fig. 5, the vertical axis indicates an average fuel consumption rate, and the horizontal axis indicates a navigation time. The fuel consumption rate as used herein refers to a ratio of the amount of fuel consumption to the navigation time. For example, the fuel consumption rate is indicated by a weight of a fuel per day (tons per day). In this case, the amount of fuel consumption can be indicated by a value that is obtained by multiplying the average fuel consumption rate by the total navigation time. It is to be noted that the breakdown of the amount of fuel consumption shown in Fig. 5 is only conceptually illustrated. The breakdown may not show an actual ratio of the amount of fuel consumption in one area.

[0042] In Fig.5, the “reference amount of fuel consumption” indicates an amount of fuel consumption when it is assumed that an increase and a decrease caused by the fuel consumption elements do not occur. Therefore, in this case, when the ship sails on a navigation time determined in advance at a constant ideal speed in ideal weather conditions, the amount of fuel consumption is equivalent to the "reference amount of fuel consumption." In this embodiment, the reference value of the amount of fuel

consumption is determined on the basis of the amount of fuel consumption that is determined in this manner.

[0043] As shown in Fig 5, the increment of the amount of fuel consumption can be divided into various elements that cause an increase in fuel consumption. According to the findings of the inventors of the present invention, there are four main elements of the fuel consumption, namely "distance sailed," "average ship speed," "weather," and "allocation of the ship speed." In Fig. 5, in addition to these fuel consumption elements, a fuel consumption element "other" is described. The fuel consumption element “other” may include an ocean current, a tidal current, a trim (a difference between a forward draft and an aft draft), loading, etc. It is assumed that the fluctuation caused by the fuel consumption element “other” is a fluctuation caused by a fuel consumption element other than the four elements "distance sailed", "average ship speed," "weather," and “allocation of the ship speed” among the fluctuations in the actual measured value with respect to the reference value of the amount of fuel consumption.

[0044] Fig. 6 is a diagram showing a method of calculating the reference amount of the fuel consumption rate. In Fig. 6, the vertical axis indicates the fuel consumption rate (a fuel oil consumption rate) of the ship, and the horizontal axis indicates the average ship speed (a ship speed over the ground). Each of the points shown in Fig. 6 indicate the measured values of the average ship speed and fuel consumption rate that are acquired based on the reference data. The points indicate measured values in various weather conditions. In fact, there may be a greater number of measured values than those illustrated. When a curvilinear regression (curve fitting) is performed using all of the measured values, curve C1 is obtained. In other words, curve C1 indicates an average relationship between the average ship speed and the fuel consumption rate.

[0045] When from these measured values, only measured values that are measured in a weather condition satisfying a specific condition (specifically, the Beaufort number is smaller than or equal to two, namely, the wind speed is smaller than or equal to 3.3 m/s) are extracted, and the curvilinear regression is performed using the extracted measured values, curve C2 is obtained. Curve C2 is a curve obtained by

using the measured values in a case of relatively good weather conditions. Similarly, when from these measured values, only measured values that are measured in the best weather condition (e.g., no wind or tail wind) are extracted, and the curvilinear regression is performed using the extracted measured values, curve C3 is obtained. When only measured values that are measured in the worst weather condition (e.g., head wind) are extracted, and the curvilinear regression is performed using the extracted measured values, curve C4 is obtained. It is to be noted that in this case it is assumed that the fuel consumption rate is proportional to the cube of the ship speed; and therefore, curves C1 to C4 are a cubic curve.

[0046] In this case, fuel efficiency is improved as the weather condition is better. For example, the fuel consumption rate of curve C3 is lower than that of curve C4 when the average speed is identical. In this embodiment, the amount of fuel consumption indicated by curve C2 is regarded as an ideal value, and is used as the reference value. The reference value of the amount of fuel consumption on the basis of curve C2 can be obtained by substituting the reference value of the average ship speed into a function indicated by curve C2 to obtain the reference value of the fuel consumption rate, and by multiplying the same by the reference value of the navigation time (the value obtained by dividing the reference value of the distance sailed by the reference value of the average ship speed). Analysis device (500) calculates the reference value of the amount of fuel consumption by performing this operation.

[0047] It is to be noted that the reference data may have any specific data format as long as the reference data indicates a relationship between an amount of fuel consumption that serves as a reference (the reference amount of fuel consumption) and at least two fuel consumption elements (reference elements) that contribute to a variation in the reference amount of fuel consumption, and also can indicate the reference amount of fuel consumption according to the combination of values of a plurality of fuel consumption elements. For example, although in this case the reference data is assumed to be data indicative of the function corresponding to curve C2, the reference data may be a look-up table that serves to return a unique value of the amount of fuel consumption when the values of the plurality of fuel consumption

elements are provided.

[0048] A curve used for determining the reference value does not have to be curve C2 (namely, measured values in the condition in which the Beaufort number is smaller than or equal to two). For example, curve C1, namely the average relationship between the average ship speed and the fuel consumption rate, may be used as the reference data. Alternatively, the reference value may be determined on the basis of a curve that is obtained by extracting measured values in a condition in which the Beaufort number is smaller than or equal to a predetermined number (other than two).

[0049] When curve C2 and the reference value of the amount of fuel consumption are determined, analysis device (500) can calculate the fluctuation in the amount of fuel consumption caused by the four fuel consumption elements "distance sailed", "average ship speed," “weather," and "allocation of the ship speed." More specifically, analysis device (500) sets the amount of fuel consumption that is obtained from the reference data (curve C2) to the reference value of the amount of fuel consumption, by using the reference value of each of the fuel consumption elements as a value of each of the fuel consumption elements. Analysis device (500) also compares, to the reference value obtained previously, an amount of fuel consumption that is obtained from the reference data (curve C2) by replacing only a value of a specific fuel consumption element among the values of fuel consumption elements with the actual measured value of the specific fuel consumption. Analysis device (500) calculates the fluctuation in the amount of fuel consumption caused by the specific fuel consumption element on the basis of the difference between them. The specific method of calculating the fluctuation in the amount of fuel consumption caused by each of the fuel consumption elements is as described below.

[0050] (Distance Sailed)

The fluctuation in the amount of fuel consumption caused by the distance sailed is obtained by multiplying the reference value of fuel consumption rate obtained from curve C2 by a difference between the actual measured value and a reference value of the distance sailed. However, in this case, it is assumed that the actual

measured value and the reference value of an average ship speed are identical. In other words, the difference between the actual measured value and the reference value of the navigation time is a value obtained by dividing the difference between the actual measured value and the reference value of the distance sailed by the reference value of the average ship speed.

[0051] (Average Ship Speed)

Fig. 7 is a diagram explaining a method of calculating the fluctuation in the amount of fuel consumption caused by the average ship speed. When the fuel consumption rate that is calculated by substituting the actual measured value of the average ship speed into the function indicated by curve C2 is used as the actual measured value of the fuel consumption rate, the fluctuation in the amount of fuel consumption caused by the average ship speed (FOC_{speed}) is obtained from formula (1.1) or (1.2) described below. In these formulae, $FOCR_0$ indicates the reference value of the fuel consumption rate; $\Delta FOCR_{speed}$ indicates a difference between the actual measured value and the reference value of the fuel consumption rate ($FOCR - FOCR_0$). NT_0 indicates the reference value of the navigation time, and NT indicates the actual measured value of the navigation time. When an actual ship speed is higher than the reference ship speed, FOC_{speed} is obtained from formula (1.1). When the actual ship speed is lower than the reference ship speed, FOC_{speed} is obtained from formula (1.2).

$$FOC_{speed} = \Delta FOCR_{speed} \times NT - FOCR \times (NT_0 - NT) \quad (1.1)$$

$$FOC_{speed} = \Delta FOCR_{speed} \times NT_0 - FOCR \times (NT_0 - NT) \quad (1.2)$$

[0052] A first term ($\Delta FOCR_{speed} \times NT$) on the right side of formula (1.1) indicates a variation in the amount of fuel consumption caused by the fuel consumption rate that is increased by the increase in the average ship speed. A second term ($- FOCR \times (NT_0 - NT)$) on the right side of formula (1.1) indicates a variation in the amount of fuel consumption caused by the navigation time that is reduced by the increase in the average ship speed. A first term ($\Delta FOCR_{speed} \times NT_0$) on the right side of formula (1.2) indicates a variation in the amount of fuel consumption caused by the fuel consumption rate that is reduced by the decrease in the average ship speed. A second term ($- FOCR \times (NT_0 - NT)$) on the right side of formula (1.2) indicates a

variation in the amount of fuel consumption caused by the navigation time that is increased by the decrease in the average ship speed. It is to be noted that the value of FOC_{speed} becomes a positive value when the average ship speed is higher than the reference value; while the value of FOC_{speed} becomes a negative value when the average ship speed is lower than the reference value. In other words, when the ship sails at an average ship seed that is lower than the reference value, the amount of fuel consumption is smaller than the reference value. Analysis device (500) can calculate the fluctuation in the amount of fuel consumption caused by the average ship speed in this manner.

[0053] (Weather)

To calculate the fluctuation in the amount of fuel consumption caused by the weather, analysis device (500) performs the curvilinear regression by using actual measured values included in the navigation data in a manner similar to that of curves C1 to C4.

Fig. 8 is a diagram showing an example of curve C5 that is obtained from the actual measured values and curve C2. Curve C5 approaches curve C2 as the weather in the navigation to be analyzed is closer to ideal weather. When the weather in the navigation to be analyzed is better than the ideal weather, curve C5 is located on the right side of curve C2. When the weather in the navigation to be analyzed is worse than the ideal weather, curve C5 is located on the left side of curve C2.

[0054] The fluctuation ($FOC_{weather}$) in the amount of fuel consumption caused by the weather is obtained from formula (2) described below. In this formula, $\Delta FOCR_{weather}$ indicates a difference between the actual measured value and the reference value of the fuel consumption rate obtained from curves C2 and C5 shown in Fig. 8, and NT indicates the actual measured value of the navigation time. In other words, $FOCR_{weather}$ is the value obtained by subtracting the reference value of the amount of the fuel consumption from an amount of fuel consumption under the assumption that the ship could sail at an average ship speed in line with the reference value in an actual weather condition indicated by the actual measured value.

$$FOC_{weather} = \Delta FOCR_{weather} \times NT \qquad (2)$$

[0055] (Allocation of Ship Speed)

As shown in Fig. 6, it is known that the fuel consumption rate does not increase in proportion to the ship speed, but is approximately proportional to the cube of the ship speed. Thus, when the ship speed is doubled, the fuel consumption rate is not doubled, but is more than doubled. Therefore, when the ship sails a predetermined distance within a predetermined time limit, the ship can sail with the lowest fuel consumption if the ship sails at a constant speed such that the ship sails the predetermined distance within the time limit. When the ship repeats acceleration and deceleration, or waits offshore (is anchored) for a long time because of arriving at the destination significantly earlier than the time limit, the fuel consumption rate is lower than that in the case where the ship sails at a constant speed even if the average ship speed is identical.

[0056] However, according to the calculations by above formulae (1.1) and (1.2), it is impossible to understand an influence of the allocation of the ship speed through the entire navigation, although only the influence of the average ship speed on the amount of fuel consumption can be understood. Therefore, to understand the amount of contribution of the allocation of the ship speed to the amount of fuel consumption, a calculation different from the calculations by formulae (1.1) and (1.2) is required.

[0057] The amount of contribution of the allocation of the ship speed to the amount of fuel consumption can be calculated by using curve C2 obtained from the reference data. Analysis device (500) firstly calculates a fuel consumption rate in the case where the ship sails at a constant speed, namely in a case where the allocation of the ship speed is ideal, by substituting the actual measured value of the average ship speed into the function indicated by curve C2. Analysis device (500) calculates an amount of fuel consumption in the case where the allocation of the ship speed is ideal by multiplying the calculated fuel consumption rate by the actual measured value of the navigation time. Analysis device (500) then calculates a fuel consumption rate and an amount of fuel consumption for each predetermined time by substituting the actual measured value of the ship speed (not the average ship speed) measured at predetermined time intervals into the function indicated by curve

C2. Analysis device (500) calculates an amount of fuel consumption on which an actual allocation of the ship speed is reflected, by integrating the same. Analysis device (500) calculates a difference between the calculated amount of fuel consumption and the amount of fuel consumption in the case where the allocation of the ship speed is ideal. The difference calculated in this manner corresponds to the fluctuation in the amount of fuel consumption caused by the allocation of the ship speed.

[0058] Fig. 9 is a diagram showing an example of the analysis report that is output as an analysis. Fig 10 is a diagram showing an example of a factor analysis included in the analysis report, namely the breakdown of the fluctuation in the amount of fuel consumption. The analysis report includes a bar chart representing the fluctuations in fuel consumption elements as shown in Fig. 10. In this case, analysis device (500) may display the breakdown obtained from the actual measured value and the past average value to allow a user to compare the two values. It is to be noted that the breakdown of the fluctuations in the amount of fuel consumption may be displayed in the analysis report in a manner using a drawing other than the bar chart, such as a table in which numerical values are described. In addition, instead of all of the fuel consumption elements shown in FIG 10, only one or more specific fuel consumption elements that are designated by the user as an element to be displayed may be displayed in the analysis report by using a drawing such as the bar chart.

[0059] As described above, according to navigational analysis system (10), it is possible to allow a user to understand a particular element in the factors contributes to a fluctuation in an amount of fuel consumption (the fuel consumption element). The user can analyze a cause of an increase or a decrease in the amount of fuel consumption by performing this analysis on the basis of navigation data acquired in navigation (namely, the actual measured value) to improve a subsequent navigation. The user can also distinguish a tendency or characteristic of navigation by each ship’s navigator, by comparing an analysis report of navigation by one ship’s navigator to an analysis report of navigation by another ship’s navigator.

[0060] [Modification]

The present invention is not limited to the above embodiment, but may be

carried out in other modes such as the following modifications. The following modifications may be combined and be carried out as necessary.

[0061] (Modification 1)

The present invention may be applied to, not only an analysis after navigation, but also an analysis before navigation. For example, the user may prepare a navigation plan prior to navigation of a ship. In this case, the user predicts in advance an amount of fuel consumption and a fuel consumption element. The user can compare a predictive value of the amount of fuel consumption or fuel consumption element with their reference value, and perform a similar analysis to that of the actual measured value, by inputting the predicted amount of fuel consumption or fuel consumption elements as prediction data. This allows the present invention to help in the preparation or revision of the navigation plan.

[0062] To implement this operation, analysis device (500) receives the input of the planning information that includes the above prediction data. Of the prediction data, a predictive value on the weather may be input by the user. Alternatively, analysis device (500) may retrieve weather information corresponding to the planned route from weather information DB (400) to use the same. It is to be noted that when the analysis using the predictive value is not performed, navigational analysis system (10) may be configured without including weather information DB (400).

[0063] Analysis device (500) may perform the analysis using the predictive value instead of the actual measured value, or alternatively, may perform both the analysis using the actual measured value and the analysis using the predictive value. When the analyses using both the actual measured value and predictive value are performed, analysis device (500) may display an analysis report in which the analysis for comparing the actual measured value with the reference value and the analysis for comparing the predictive value with the reference value are described together. Fig. 11 is a diagram showing an example of the analysis report in which the analyses are described together.

[0064] (Modification 2)

The reference value of the present invention does not have to be acquired on the

basis of the actual navigation of the ship. For example, the reference value may be any numerical value that is acquired by computer simulation and so forth. Alternatively, the reference data may be generated by performing a trial run at sea (a test) using an actual ship, and by measuring the ship speed and the amount of fuel consumption during the trial run. Alternatively, the reference data may be generated by using data acquired in a model test (towing tank test) at a design stage of the ship. The reference data may be provided as, not a set of measured values as described above, but a function used for a calculation to return a desired reference value in response to an input variable.

[0065] Furthermore, the present invention may use the above predictive value (prediction data) as the reference value (reference data) to perform the analysis by comparing the actual measured value with the predictive value. This comparison allows the user to understand a degree of the coincidence (or difference) between the navigation plan and actual navigation for each of the fuel consumption elements. In addition, since the actual measured value and the predictive value are compared, the present invention can be applied to navigation on an irregular route for which there is no (or less) past measured value.

[0066] (Modification 3)

The fuel consumption elements for which the breakdown is calculated in the present invention are not limited to the four elements "distance sailed," "average ship speed," "weather," and "allocation of the ship speed." Any number of fuel consumption elements may be used as long as the number is greater than or equal to two. For example, oceanographic phenomena may be used as the fuel consumption elements instead of the weather, or both the weather and oceanographic phenomena may be used as the fuel consumption elements. Alternatively, the wind power, the wind direction, the tidal current, the ocean current, the wave height, etc. may be used as fuel consumption elements to calculate their breakdown by subdividing the weather and the oceanographic phenomena. Furthermore, a state of a hull such as the trim or loading may be used as a fuel consumption element to calculate its breakdown.

[0067] It is to be noted that estimated values may be used for the fuel consumption

elements instead of the actual measured values. For example, if a position (latitude and longitude) of the ship at a certain time can be identified, even if the weather at the time is not actually measured, the weather can be estimated. Therefore, the estimated value acquired in this manner can be used.

[0068] (Modification 4)

In the present invention, the reference amount of fuel consumption may be determined by a method other than regression analysis. For example, the reference amount of fuel consumption may be calculated by estimating the influence caused by the weather (namely, the increase or decrease in the amount of fuel consumption), and by excluding the influence caused by the weather from the measured value of the fuel consumption rate, for each measured value shown in Fig. 6.

[0069] (Modification 5)

The navigation to be analyzed in the present invention may be a part of navigation, rather than the entire navigation from a departure point to a destination. For example, analysis device (500) may perform an analysis of the navigation in a specific sea area corresponding to a part of navigation. Alternatively, analysis device (500) may divide the entire sea area into smaller sea areas, and may perform an analysis for each of the smaller sea areas.

[0070] (Modification 6)

The output of the present invention is not limited to information for visualizing the amount of fuel consumption, but may be information quantifying a fuel cost or representing the fuel cost in a graphic form. In this case, it is possible to present to a user the fuel cost or a fluctuation in the fuel cost to allow the user to analyze the same, by multiplying an amount of fuel consumption or a fluctuation in the amount of fuel consumption that is calculated by the calculation means by a unit cost of the fuel.

[0071] (Modification 7)

The navigational analysis device according to the present invention is not limited to a device such as analysis device (500) described above. For example, the navigational analysis device according to the present invention may be implemented by a server device connected to a network to allow a user to access the server device

via a client device (a personal computer, a smart phone, etc.). In this case, the analysis report may be described in an HTML (HyperText Markup Language) or the like to be provided on a web page. Alternatively, the analysis report may be provided by email.

[0072] The present invention may be understood not only as a navigational analysis device or a navigational analysis system that includes the navigational analysis device, but also as a navigational analysis method in which the navigational analysis device is used, a program for causing a computer to function as the navigational analysis device of the present invention, and so forth. Furthermore, the program according to the present invention may be provided by being stored in a recording medium such as an optical disk, or may be provided by being downloaded to the computer via a network such as the Internet and by being installed into the computer so as to be made available to users.

DESCRIPTION OF REFERENCE NUMERALS

[0073] 10…Navigational analysis system, 100…Communication device, 200…Network, 300…Navigation information DB, 400…Weather information DB, 500…Analysis device, 510…Control unit, 511…First acquisition means, 512…Second acquisition means, 513…Calculation means, 514…Output means, 520…Storage unit, 530…Communication unit, 540…Operation input unit, 550…Display unit

CLAIMS

[Claim 1] A navigational analysis device comprising:

a first acquisition means that acquires navigation data indicative of both an amount of fuel consumption in navigation of a ship and at least two elements contributing to a variation in the amount of fuel consumption in the navigation;

a second acquisition means that acquires reference data indicative of a reference amount of fuel consumption;

a calculation means that calculates, based on the navigation data and the reference data, a fluctuation caused by at least one element of the at least two elements, the fluctuation being included in a fluctuation in the amount of fuel consumption indicated by the navigation data with respect to the reference amount of fuel consumption; and

an output means that outputs a calculation made by the calculation means.

[Claim 2] The navigational analysis device according to Claim 1, wherein:

the reference data includes data indicative of a relationship between the reference amount of the fuel consumption and at least two reference elements that contribute to a variation in the reference amount of fuel consumption; and

the calculation means calculates, based on a difference between the reference amount of fuel consumption and an amount of fuel consumption that is obtained based on the reference data by using the navigation data as a value of a first element of the at least two elements, and by using the reference element as a value of a second element, a fluctuation caused by the first element.

[Claim 3] The navigational analysis device according to Claim 2, wherein:

the calculation means calculates the fluctuation by using each of values of the at least two elements as the first element.

[Claim 4] The navigational analysis device according to Claim 2 or 3, wherein:

the reference data includes a plurality of sets of data indicative of a relationship between an actual measured value of an amount of fuel consumption measured in another navigation of the navigation and the at least two reference elements; and

the calculation means determines the reference amount of fuel

consumption by using a plurality of actual measured values of amounts of fuel consumption included in the reference data.

[Claim 5] The navigational analysis device according to Claim 4, wherein:

the calculation means determines the reference amount of fuel consumption based on a result of a regression analysis, the regression analysis being performed by using data that satisfies a specific weather condition among a plurality of sets of data indicative of a relationship between an actual measured value of an amount of fuel consumption included in the reference data and the at least two reference elements.

[Claim 6] The navigational analysis device according to any one of Claims 1 to 5, wherein:

the first acquisition means acquires prediction data indicative of both a predictive value of an amount of fuel consumption in navigation of the ship and a predictive value of the element; and

the calculation means calculates, based on the prediction data and the reference data, a fluctuation caused by at least one element of the at least two elements, the fluctuation being included in a fluctuation in the amount of fuel consumption indicated by the prediction data with respect to the reference amount of fuel consumption.

[Claim 7] The navigational analysis device according to any one of Claims 1 to 5, wherein:

the second acquisition means acquires, as the reference data, prediction data indicative of both a predictive value of an amount of fuel consumption in navigation of the ship and a predictive value of the element.

[Claim 8] The navigational analysis device according to any one of Claims 1 to 7, wherein:

the element is an element relating to at least one of a distance sailed, a ship speed, weather, and an oceanographic phenomenon.

[Claim 9] A navigational analysis method comprising:

a first step of acquiring navigation data indicative of both an amount of fuel consumption in navigation of a ship and at least two elements contributing

to a variation in the amount of fuel consumption in the navigation;

a second step of acquiring reference data indicative of a reference amount of fuel consumption;

a third step of calculating, based on the navigation data and the reference data, a fluctuation caused by at least one element of the at least two elements, the fluctuation being included in a fluctuation in the amount of fuel consumption indicated by the navigation data with respect to the reference amount of fuel consumption; and

a fourth step of outputting a calculation made in the third step.

[Claim 10] A program for causing a computer to execute:

a first step of acquiring navigation data indicative of both an amount of fuel consumption in navigation of a ship and at least two elements contributing to a variation in the amount of fuel consumption in the navigation;

a second step of acquiring reference data indicative of a reference amount of fuel consumption;

a third step of calculating, based on the navigation data and the reference data, a fluctuation caused by at least one element of the at least two elements, the fluctuation being included in a fluctuation in the amount of fuel consumption indicated by the navigation data with respect to the reference amount of fuel consumption; and

a fourth step of outputting a calculation made in the third step.

[Claim 11] A computer-readable recording medium storing a program for causing a computer to execute:

a first step of acquiring navigation data indicative of both an amount of fuel consumption in navigation of a ship and at least two elements contributing to a variation in the amount of fuel consumption in the navigation;

a second step of acquiring reference data indicative of a reference amount of fuel consumption;

a third step of calculating, based on the navigation data and the reference data, a fluctuation caused by at least one element of the at least two elements, the fluctuation being included in a fluctuation in the amount of fuel consumption

indicated by the navigation data with respect to the reference amount of fuel consumption; and

a fourth step of outputting a calculation made in the third step.