SPECIFICATION

TITLE OF INVENTION:

APPARATUS FOR PREVENTING OCCURRENCE OF ABNORMAL INCIDENTS IN SHIP, PROGRAM, AND STORAGE MEDIUM

TECHNICAL FIELD

[0001] The present invention relates to a technique for preventing the occurrence of abnormal incidents in a ship.

BACKGROUND ART

[0002] In an apparatus such as a main engine or a power generator mounted on a ship, abnormal incidents occur in some cases due to faulty maintenance, breakdown, or the like. A technique for preventing the occurrence of these abnormal incidents (hereinafter referred to as “trouble”) has been proposed. For example, Patent Document 1 proposes a system for preventing trouble caused by a ship engine. The system according Patent Document 1 includes a first information processing apparatus that is arranged on a ship and collects and transmits data relating to the ship engine, and a second information processing apparatus that is arranged in an engineering center and performs diagnosis and lifespan prediction of the ship engine based on the data transmitted from the first information processing apparatus. With the system according to Patent Document 1, the service center can design a maintenance plan for the ship engine and prepare maintenance parts based on the results of the diagnosis and lifespan prediction performed by the second information processing apparatus. As a result, trouble in the ship engine is prevented.

PRIOR ART DOCUMENT

PATENT DOCUMENT

[0003] Patent Document 1: JP 2002-183341A

SUMMARY OF THE INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

[0004] Most trouble that occurs in a ship is pre-indicated in some manner before it occurs. Accordingly, an engineer performing maintenance of an apparatus on a ship senses a pre-indication of trouble based on various types of information and prevents the occurrence of trouble by taking a countermeasure before the trouble occurs. Accordingly, if an engineer overlooks these pre-indications, there is a risk that trouble will occur.

[0005] In view of the foregoing circumstances, the present invention provides a means for estimating the likelihood of occurrence of an abnormal incident in a ship.

MEANS FOR SOLVING THE PROBLEM

[0006] In order to solve the above-described problem, the present invention provides, as a first aspect, an apparatus including: an acquisition means for acquiring cause-effect relationship data indicating a cause-effect relationship between a plurality of incidents that occur in a ship, and attribute value data indicating, for each of one or more incidents for which an incident serving as a cause is not indicated by the cause-effect relationship data, an attribute value of the ship or an environment in which the ship is located, relating to an occurrence of the incident; and an estimation means for estimating a likelihood of occurrence of each of the plurality of incidents based on the cause-effect relationship data and the attribute value data.

[0007] In the apparatus according to the above-described first aspect, it is

also possible to employ, as a second aspect, a configuration in which for each of the one or more incidents for which an incident serving as a cause is not indicated by the cause-effect relationship data, the acquisition means acquires reference value data indicating a reference value of an attribute value of the ship or the environment in which the ship is located, relating to the incident, and for each of the one or more incidents for which an incident serving as a cause is not indicated by the cause-effect relationship data, the estimation means estimates the likelihood of occurrence of the incident based on the result of comparing an attribute value indicated by the attribute value data relating to the incident and a reference value indicated by the reference value data relating to the incident.

[0008] In the apparatus according to the above-described first aspect, it is also possible to employ, as a third aspect, a configuration in which for each of at least one of the one or more incidents for which an incident serving as a cause is not indicated by the cause-effect relationship data, the acquisition means acquires the attribute value data indicating a plurality of attribute values of the ship or the environment in which the ship is located, relating to the incident, for each of the at least one incident, the acquisition means acquires reference value data indicating a reference combination of a plurality of attribute values relating to the incident, and for each of the at least one incident, the estimation means estimates the likelihood of occurrence of the incident based on the result of comparing the combination of the plurality of attribute values indicated by the attribute value data and the reference combination of the plurality of attribute values indicated by the reference value data.

[0009] In the apparatus according to any one of the above-described first to third aspects, it is also possible to employ, as a fourth aspect, an configuration in which the cause-effect relationship data indicates a tree

structure in which the plurality of incidents are nodes, and a contribution level according to which, in each node group in a parent-child relationship in the tree structure, the likelihood of occurrence of an incident of a child node included in the node group contributes to the likelihood of occurrence of an incident of a parent node included in the node group, and for each of one or more leaf nodes in the tree structure, the estimation means estimates the likelihood of occurrence of an incident of the leaf node based on the attribute value data relating to the incident of the leaf node, and estimates the likelihood of occurrence of an incident of an internal node in the tree structure in order from a leaf node side to a root node side based on the estimated likelihood of occurrence of the incident of the leaf node and the contribution level indicated by the cause-effect relationship data.

[0010] In the apparatus according to any one of the above-described first to fourth aspects, it is also possible to employ, as a fifth aspect, a configuration including a notification means for performing processing for performing notification of the incident to a user if the likelihood of occurrence estimated by the estimation means exceeds a predetermined threshold value.

[0011] In the apparatus according to the above-described fifth aspect, it is also possible to employ, as a sixth aspect, a configuration including a specifying means for specifying the incident that contributes the most to an increase in the likelihood of occurrence of an incident for which the likelihood of occurrence estimated by the estimation means exceeds a predetermined threshold value, wherein the notification means performs processing for performing notification of the incident specified by the specifying means to the user.

[0012] Also, the present invention provides, as a seventh aspect, a program for causing a computer to execute: processing for acquiring cause-effect

relationship data indicating a cause-effect relationship between a plurality of incidents that occur in a ship, and attribute value data indicating, for each of one or more incidents for which an incident serving as a cause is not indicated by the cause-effect relationship data, an attribute value of the ship or an environment in which the ship is located, relating to an occurrence of the incident; and processing for estimating a likelihood of occurrence of each of the plurality of incidents based on the cause-effect relationship data and the attribute value data.

[0013] Also, the present invention provides, as an eighth aspect, a computer-readable storage medium permanently storing a program for causing a computer to execute: processing for acquiring cause-effect relationship data indicating a cause-effect relationship between a plurality of incidents that occur in a ship, and attribute value data indicating, for each of one or more incidents for which an incident serving as a cause is not indicated by the cause-effect relationship data, an attribute value of the ship or an environment in which the ship is located, relating to an occurrence of the incident; and processing for estimating a likelihood of occurrence of each of the plurality of incidents based on the cause-effect relationship data and the attribute value data.

EFFECTS OF THE INVENTION

[0014] According to the present invention, the likelihood of occurrence of an abnormal incident in a ship can be estimated. As a result, a user such as an engineer of the ship can take a countermeasure for preventing the occurrence of trouble.

BRIEF EXPLANATION OF THE DRAWINGS

[0015] [FIG. 1] A diagram showing an overall configuration of a system

according to an embodiment.

[FIG. 2] A diagram showing a configuration of a computer to be used as hardware of a server apparatus according to an embodiment.

[FIG. 3] A diagram showing a configuration of a computer to be used as hardware of a terminal apparatus according to an embodiment.

[FIG. 4] A diagram showing a functional configuration of a server apparatus according to an embodiment.

[FIG. 5] A diagram showing a configuration of an attribute value table stored in a server apparatus according to an embodiment.

[FIG. 6] A diagram showing a functional configuration of a server apparatus according to an embodiment.

[FIG. 7] A diagram showing a configuration of cause-effect relationship data stored in a server apparatus according to an embodiment.

[FIG. 8] A tree diagram used to create a cause-effect relationship tree diagram according to an embodiment.

[FIG. 9] A cause-effect relationship tree diagram according to an embodiment.

[FIG. 10] A graph used by a server apparatus according to an embodiment to specify a risk index.

[FIG. 11] A diagram showing a flow of processing performed by a server apparatus according to an embodiment to specify a risk index.

[FIG. 12] A diagram showing a configuration of a risk index log table stored in a server apparatus according to an embodiment.

[FIG. 13] A diagram showing a functional configuration of a terminal apparatus according to an embodiment.

[FIG. 14] A diagram illustrating a screen displayed on a terminal apparatus according to an embodiment.

[FIG. 15] A diagram illustrating a screen displayed on a terminal apparatus according to an embodiment.

MODES FOR CARRYING OUT THE INVENTION

[0016] [Exemplary embodiment]

System 1 according to an embodiment of the present invention will be described hereinafter. System 1 is a system that estimates the likelihood of occurrence of trouble in a ship, and arouses caution in the user if the estimated likelihood exceeds a predetermined threshold.

[0017] FIG. 1 is a diagram showing the overall configuration of system 1. System 1 includes: n (n being any integer) measurement apparatuses, that is, measurement apparatuses 11-1, 11-2, ..., and 11-n (these measurement apparatuses will hereinafter be referred to as "measurement apparatus group 11"); server apparatus 12; server apparatus 13; terminal apparatus 14; and terminal apparatus 15. Measurement apparatus group 11, server apparatus 12, and terminal apparatus 15 are arranged on ship 9, and server apparatus 13 and terminal apparatus 14 are arranged on land.

[0018] Although one ship 9 is shown in FIG. 1, multiple ships 9 may be managed by system 1. If multiple ships 9 are managed by system 1, system 1 includes measurement apparatus groups 11, server apparatuses 12, and terminal apparatuses 15 corresponding to multiple ships 9. Also, in FIG. 1, although one terminal apparatus 15 is arranged in one ship 9, multiple terminal apparatuses 15 may be arranged in one ship 9. Also, although one terminal apparatus 14 is shown in FIG. 1, system 1 may also include multiple terminal apparatuses 14.

[0019] The n measurement apparatuses included in measurement apparatus group 11 are various types of measurement apparatuses, such as a main engine revolution meter, a power meter of generator, and a wind speed/wind direction meter. That is, each of the measurement apparatuses included in measurement apparatus group 11 measures an attribute value of ship 9 or of the environment in which ship 9 is located.

Hereinafter, the data indicating the measurement results of each of the measurement apparatuses included in measurement apparatus group 11 will be referred to as “attribute value data”.

[0020] Server apparatus 12 is an apparatus that receives attribute value data from each of the measurement apparatuses included in measurement apparatus group 11, and transmits the received attribute value data to server apparatus 13. Note that data communication between server apparatus 12 and server apparatus 13 is performed via communication satellite 8. Server apparatus 13 is an apparatus that estimates the likelihood of occurrence of trouble (abnormal incidents) in ship 9 based on the attribute value data transmitted from server apparatus 12, and performs notification of the result of the estimation to terminal apparatus 14 and terminal apparatus 15.

[0021] Terminal apparatus 14 is an apparatus that displays the result of the estimation performed by server apparatus 13 to a user on land (e.g., an employee of an owner company of ship 9, an employee of a management company of ship 9, etc.). Also, terminal apparatus 15 is an apparatus that displays the result of the estimation performed by server apparatus 13 to a user on ship 9 (e.g., a crew member of ship 9, etc.). Note that data communication between server apparatus 13 and terminal apparatus 15 is performed via communication satellite 8.

[0022] The hardware of server apparatus 12 and server apparatus 13 is a general computer for a server apparatus, for example. FIG. 2 is a diagram showing a configuration of computer 10, which is used as the hardware of server apparatus 12 or server apparatus 13. Computer 10 includes: memory 101 for storing various types of data; processor 102 for performing various types of data processing in accordance with a program stored in memory 101; and communication IF 103, which is an interface for performing data communication with an external apparatus.

Communication IF 103 of computer 10, which is used as the hardware of server apparatus 12, performs data communication with each of the measurement apparatuses included in measurement apparatus group 11 via a communication network in ship 9, and performs data communication with server apparatus 13 via communication satellite 8. Also, communication IF 103 of computer 10, which is used as the hardware of server apparatus 12, performs data communication with terminal apparatus 14 via an on-land communication network, and performs data communication with server apparatus 12 and terminal apparatus 15 via communication satellite 8.

[0023] The hardware of terminal apparatus 14 and terminal apparatus 15 is a general computer for a terminal apparatus, for example. FIG. 3 is a diagram showing a configuration of computer 20, which is used as the hardware of terminal apparatus 14 or terminal apparatus 15. Computer 20 includes: memory 201 for storing various types of data; processor 202 for performing various types of data processing in accordance with a program stored in memory 201; communication IF 203, which is an interface for performing data communication with an external apparatus; display apparatus 204, such as a liquid crystal display for displaying an image to a user; and operation apparatus 205 such as a keyboard for receiving a user operation. Note that an externally-attached display apparatus that is connected to computer 20 may also be used instead of or in addition to display apparatus 204 that is built in computer 20. Also, an externally-attached operation apparatus that is connected to computer 20 may also be used instead of or in addition to operation apparatus 205 that is built in computer 20.

[0024] FIG. 4 is a diagram showing a functional configuration of server apparatus 12. That is, computer 10, which constitutes the hardware of server apparatus 12, operates as an apparatus that includes the

configurational units shown in FIG. 4, by executing data processing in accordance with a program for server apparatus 12. Hereinafter, the configurational units of server apparatus 12 shown in FIG. 4 will be described.

[0025] Acquisition means 121 is constituted mainly by communication IF 103 and acquires attribute value data that is output from the measurement apparatuses included in measurement apparatus group 11. Storage means 122 is constituted mainly by memory 101 and stores the attribute value data acquired by acquisition means 121. Storage means 122 stores a table (hereinafter referred to as “attribute value table”) for storing the attribute value data corresponding to the measurement apparatuses included in measurement apparatus group 11.

[0026] FIG. 5 is a diagram showing a configuration of an attribute value table stored in storage means 122. Upon the occurrence of a specific event, such as the elapse of a predetermined amount of time, for example, the measurement apparatuses included in measurement apparatus group 11 each perform measurement of an attribute value and output attribute value data indicating the measurement result. The attribute value table is a collection of data records corresponding to these measurements. The attribute value table has the data fields “measurement time” and “attribute value”. Data indicating the times of measurement performed by the measurement apparatuses is stored in the data field “measurement time”. Note that the times of measurement performed by the measurement apparatuses may also be times measured by a measurement apparatus, and for example, may also be times at which server apparatus 12 received attribute value data from the measurement apparatuses. The attribute value data indicating the results of measurement performed by the measurement apparatuses, that is, the attribute values, is stored in the data field “attribute value”.

[0027] Description of the configuration of server apparatus 12 will be continued with reference to FIG. 4. Transmission means 123 is constituted mainly by communication IF 103, and each time a predetermined amount of time elapses, for example, transmission means 123 transmits the untransmitted attribute value data stored in storage means 122 to server apparatus 13.

[0028] FIG. 6 is a diagram showing a functional configuration of server apparatus 13. That is, computer 10, which constitutes the hardware of server apparatus 13, operates as an apparatus that includes the constituent units shown in FIG. 6, by executing data processing in accordance with a program for server apparatus 13. Hereinafter, the constituent units of server apparatus 13 shown in FIG. 6 will be described.

[0029] Acquisition means 131 is constituted mainly by communication IF 103 and acquires various types of data transmitted from server apparatus 12 or terminal apparatus 14. The data acquired by acquisition means 131 includes, in addition to the attribute value data transmitted from server apparatus 12, cause-effect relationship data indicating the cause-effect relationship between multiple incidents that occur in ship 9, and reference value data indicating reference values for attribute values of ship 9 or the environment in which ship 9 is located, for each of the incidents for which an incident serving as a cause is not indicated by the cause-effect relationship data. The cause-effect relationship data and reference value data are, for example, pieces of data that are input to terminal apparatus 14 by the user of terminal apparatus 14 and are transmitted from terminal apparatus 14 to server apparatus 13.

[0030] Storage means 132 is constituted mainly by memory 101 and stores the various types of data acquired by acquisition means 131. First, the

attribute value table for storing the attribute value data acquired from server apparatus 12 is stored in storage means 132. The attribute value table has a similar configuration to the attribute value table stored in storage means 132 of server apparatus 13 (see FIG. 5). However, if multiple ships 9 are managed by system 1, a group of attribute value tables corresponding to multiple ships 9 is stored in storage means 132.

[0031] Also, storage means 132 stores cause-effect relationship data corresponding to each kind of trouble that the user wants to prevent the occurrence of. Note that if multiple ships 9 are managed by system 1, storage means 132 stores a cause-effect relationship data group corresponding to each of multiple ships 9.

[0032] FIG. 7 is a diagram showing a configuration of cause-effect relationship data stored in storage means 132. The cause-effect relationship data is data that indicates a tree structure in which multiple incidents relating to trouble each serve as a node, and indicates rules for specifying the likelihood of occurrence of the incidents corresponding to the nodes. The cause-effect relationship data is, for example, data created by the user of terminal apparatus 14 (e.g., an employee of a management company of ship 9, etc.). Hereinafter, the tree structure, which is indicated by the cause-effect relationship data and in which the multiple incidents relating to trouble each serve as a node, will be described.

[0033] First, a creator of the cause-effect relationship data (hereinafter simply referred to as “creator”) thinks of a direct cause that results in trouble that is to be prevented. Hereinafter, as an example, a case is envisioned in which the trouble to be prevented is a “scavenging space fire”. In this case, as direct causes that result in a scavenging space fire, the creator thinks of “oxygen”, “heat source (e.g., occurrence of blow-by gas)”, and “combustible material (e.g., accumulation of

sludge)” , for example. Next, the creator thinks of direct causes resulting in each of the causes. In this case, the creator thinks that “oxygen” is a fundamental cause for which it is not necessary to think of a further cause. On the other hand, the creator thinks of “damage to piston ring or progression of wear of cylinder liner” as an example of a direct cause resulting in “heat source (e.g., occurrence of blow-by gas)”. Also, the creator thinks of “incomplete combustion” and “clogging of drain pipe” as examples of direct causes resulting in “combustible material (e.g., accumulation of sludge)”.

[0034] FIG. 8 is a tree diagram for organizing the relationships between the multiple causes resulting in a scavenging space fire, which were thought of as described above by the creator. The creator repeats the above-described task until all of the causes located at the terminal ends of the tree diagram shown in FIG. 8 are fundamental causes for which it is not necessary to think of further causes.

[0035] Next, the creator reconfigures the incidents serving as causes included in the organized tree diagram to be incidents that can be evaluated using an attribute value (or a combination of multiple attribute values) measured by a measurement apparatus included in the measurement apparatus group 11. FIG. 9 results from the operator reconfiguring the tree diagram of FIG. 8 to be a tree diagram constituted by incidents that can be evaluated using an attribute value (or a combination of multiple attribute values). Hereinafter, the tree diagram expressing the relationship between the trouble in the ship and its causes, as shown in FIG. 9, will be referred to as a “cause-effect relationship tree diagram”.

[0036] The structure of the data expressed by the tree diagram is generally called a tree structure, and the multiple elements constituting the data of the tree structure are called nodes. The nodes serving as the bases of

the nodes in the data of the tree structure are called root nodes, and the nodes at the terminal ends are called leaf nodes. Also, the node on the root node side of two associated nodes is called a parent node, and the node on the leaf node side is called a child node. Accordingly, a root node is a node that does not have a parent node, and a leaf node is a node that does not have a child node. Also, multiple nodes with the same parent node are called sibling nodes. Also, a node having a parent node and a child node is called an internal node.

[0037] In the cause-effect relationship tree diagram of FIG. 9, reference numerals such as “N1” and “N11”, which are attached to each element, are node IDs that identify the nodes. Node N1 “scavenger chamber fire” in the cause-effect relationship tree diagram of FIG. 9 is a root node, and corresponds to trouble that is to be prevented. Also, node N1111 “engine load and exhaust gas temperature”, node N11131 “scavenging air pressure and first supercharger rotation rate”, and the like in the cause-effect relationship tree diagram of FIG. 9 are leaf nodes, and correspond to incidents that are directly evaluated using an attribute value (or a combination of multiple attribute values) measured by the measurement apparatuses included in the measurement apparatus group 11.

[0038] Note that the incidents shown in the tree diagram of FIG. 8 and the nodes of the cause-effect relationship tree diagram of FIG. 9 do not necessarily need to be in one-to-one correspondence.

[0039] The tree structure expressed by the cause-effect relationship tree diagram shown in FIG. 9 is the tree structure indicated by the cause-effect relationship data shown in FIG. 7. Hereinafter, the configuration of the cause-effect relationship data shown in FIG. 7 will be described.

[0040] The cause-effect relationship data is a collection of data records

corresponding to the multiple nodes constituting the data of the tree structure. The cause-effect relationship data includes the data fields “node ID”, “node name”, “parent node”, “child node”, “risk index calculation condition”, “weight”, and “maximum value”. The data stored in “node ID”, “node name”, “parent node”, and “child node” among these data fields is data indicating the tree structure expressed by the cause-effect relationship tree diagram.

[0041] The node ID is stored in the data field “node ID”. Data indicating the name of the incident corresponding to the node is stored in the data field “node name”. The node ID of the parent node is stored in the data field “parent node”. The node ID of the child node is stored in the data field “child node”.

[0042] Data indicating a rule for specifying an index (hereinafter referred to as “risk index”) indicating the likelihood of occurrence of the incident corresponding to the node is stored in the data field “risk index specifying rule” of the cause-effect relationship data. For example, the risk index specifying rule “weighted average” of node N1 shown in FIG. 7 indicates that the weighted average of the risk indices of the child nodes (nodes N11, N12, ...) of node N1 is to be the risk index of node N1.

[0043] Also, the risk index specifying rule “if R(N112)>700 then R(N11)=R(N112), else weighted average” of node N11 indicates that if the risk index of node N112 is greater than 700, the risk index of node N112 is to be the risk index of node N11; otherwise, that is, if the risk index of node N112 is 700 or less, the weighted average of the risk indices of the child nodes, that is, node N111 and node N112, is to be the risk index of node N11. Note that “R( )” means the risk index of the node identified by the node ID in “( )”. In this manner, the risk index relating to a parent node or an internal node is specified based on

the risk indices of child nodes.

[0044] Also, the risk index specifying rule "graph G035, R=D×#" of node N1121 means that a number obtained by multiplying distance D in the y-axis direction between a reference line indicated by the graph with the name "graph G035" and a point indicating the combination of attribute values corresponding to node N1121 (main engine load and average cylinder exhaust gas temperature) by a constant # is to be the risk index of node N1121.

[0045] FIG. 10 is a diagram for describing graph G035, a method for generating graph G035, and the like. In FIG. 10, the x axis indicates the main engine load, and the y axis indicates the average cylinder exhaust gas temperature (average value of exhaust gas temperature of each of multiple cylinders). The many dots (scatter diagram) shown in FIG. 10 are dots resulting from plotting samples of a combination of the main engine load and the average cylinder exhaust gas temperature measured in ship 9 (or a group of ships of the same type as ship 9) in the past. Line M in FIG. 10 is a trend line (e.g., a polynomial trend line) indicating the trend of the samples indicated by the many dots. Line M is graph G035.

[0046] The data indicating graph G035 (line M) is used as reference value data indicating a reference combination of multiple attribute values, namely the main engine load and the average cylinder exhaust gas temperature. For example, the sample indicated by dot S in FIG. 10 is distance D away from graph G035 (line M) in the y-axis direction. The larger distance D is, the farther away from the normal state ship 9 is when in the state of the sample indicated by dot S. Accordingly, it is evaluated that the larger distance D is, the higher the likelihood that an unfavorable incident will occur.

[0047] However, the relationship between distance D and the likelihood of

occurrence of the incident differs depending on the type of the incident of interest. “R(N1121)=D×#”, which is indicated in the risk index specifying rule of node N1121 of FIG. 7, means that if node N1121 is determined as the cause of the trouble “scavenger chamber fire”, a number obtained by multiplying distance D by constant # is suitable as the risk index indicating the contribution level of the combination of the main engine load and the average cylinder exhaust gas temperature.

[0048] In this manner, a risk index for a leaf node is specified based on the result of comparing an attribute value (or combination of multiple attribute values) measured by a measurement apparatus included in the measurement apparatus group 11 and a reference value.

[0049] Description of the configuration of the cause-effect relationship data will be continued with reference to FIG. 7. If a weighted average is to be used as the risk index specifying rule, data indicating the weight to be used in the weighted average is stored in the data field “weight” of the cause-effect relationship data. In the example shown in FIG. 7, for example, the risk index of node N1 is calculated by finding the weighted average of the risk indices of nodes N11, N12, and N13, which are child nodes of node N1. In the calculation of the weighted average, for example, the weight by which to multiply the risk index of node N11 is stored in the data field “weight” of the data record corresponding to node N11.

[0050] Note that the data stored in the data field “weight” indicates the contribution level to which the likelihood of the occurrence of the incident corresponding to the target node contributes to the likelihood of the occurrence of the incident of the parent node in the comparison of incidents corresponding to sibling nodes of a target node.

[0051] The data indicating the maximum value of the risk index is stored in the data field “maximum value” of the cause-effect relationship data.

If the risk index calculated in accordance with the rule indicated by the data stored in the data field “risk index specifying rule” exceeds the maximum value indicated by the data stored in the data field “maximum value”, the maximum value is employed as the risk index instead of the risk index calculated in accordance with the rule. Accordingly, even if an abnormal risk index is calculated due to damage or the like of the measurement apparatus, the abnormal risk index has a limited influence on the risk index of the root node.

[0052] The configuration of the cause-effect relationship data has been described above. Note that in addition to the cause-effect relationship data, storage means 132 also stores data indicating various graphs to be referenced according to the data stored in the data field “risk index specifying rule” of the cause-effect relationship data.

[0053] Description of the configuration of server apparatus 13 will be continued with reference to FIG. 6. Estimation means 133 is constituted mainly by processor 102, and estimates the likelihood of occurrence of the incidents corresponding to the nodes of the cause-effect relationship tree diagram based on the attribute value data that has been acquired by acquisition means 131 from server apparatus 12 and stored in storage means 132, and the cause-effect relationship data that has been acquired by acquisition means 131 from terminal apparatus 14 and stored in storage means 132. More specifically, estimation means 133 specifies the risk indices corresponding to the nodes. Hereinafter, a procedure according to which estimation means 133 specifies the risk indices corresponding to the nodes will be described.

[0054] FIG. 11 is a diagram showing a flow of processing performed by estimation means 133 in order to specify a risk index. Each time a predetermined amount of time elapses, for example, estimation means

133 selects one leaf node and reads out the data record corresponding to the selected leaf node from the cause-effect relationship data (see FIG. 9) (step S001). Next, estimation means 133 reads out the newest attribute value data from the attribute value table (see FIG. 5) corresponding to the attribute value (or combination of attribute values) indicated by the data stored in the data field "node name" of the data record of the leaf node read out in step S001 (step S002).

[0055] Next, in accordance with the rule indicated by the data stored in the data field "risk index specifying rule" in the data record of the leaf node read out in step S001, estimation means 133 specifies the risk index corresponding to the attribute value (or the combination of multiple attribute values) indicated by the attribute value data read out in step S002 (step S003).

[0056] A table corresponding to each node (hereinafter referred to as "risk index log table") is stored in storage means 132 in order to store the risk indices specified by estimation means 133. FIG. 12 is a diagram showing a configuration of a risk index log table. Upon specifying the risk index in step S003, estimation means 133 adds a new data record to the risk index log table corresponding to the node ID stored in the data field "node ID" of the data record read out in step S001, stores data indicating the current time in the data field "time" of the added data record, and stores the risk index specified in step S003 in the data field "risk index" (step S004).

[0057] Next, estimation means 133 determines whether or not all leaf nodes have been selected in the selection of the leaf nodes in step S001 executed in the past (step S005). If there is an unselected leaf node (step S005; No), estimation means 133 returns the processing to step S001, selects one unselected leaf node, and reads out the data record corresponding to the selected leaf node from the cause-effect

relationship data, and thereafter repeats the processing of step S002 and onward for the read-out data record.

[0058] If all leaf nodes have been selected (step S005; Yes), estimation means 133 selects one internal node for which the risk indices of all child nodes have been specified and reads out the data record corresponding to the selected internal node from the cause-effect relationship data (see FIG. 9) (step S006). Next, in accordance with the rule indicated by the data stored in the data field “risk index specifying rule” in the data record of the internal node read out in step S006, estimation means 133 specifies the risk index of the internal node selected in step S006 using the risk indices of the child nodes (step S007).

[0059] Upon specifying the risk index in step S007, estimation means 133 adds a new data record to the risk index log table corresponding to the node ID stored in the data field “node ID” of the data record read out in step S006, stores data indicating the current time in the data field “time” of the added data record, and stores the risk index specified in step S007 in the data field “risk index” (step S008).

[0060] Next, estimation means 133 determines whether or not all internal nodes have been selected in the selection of the internal nodes in step S006 executed in the past (step S009). If there is an unselected internal node (step S009; No), estimation means 133 returns the processing to step S006, selects one unselected internal node, and reads out the data record corresponding to the selected internal node from the cause-effect relationship data, and thereafter repeats the processing of step S007 and onward for the read-out data record.

[0061] Note that in step S006, which is executed repeatedly, the internal nodes are selected in order from the leaf node side to the root node side. Accordingly, the risk indices are specified sequentially in order from the

leaf node side to the root node side.

[0062] If all of the internal nodes have been selected (step S009; Yes), estimation means 133 reads out the data record corresponding to the parent node from the cause-effect relationship data (see FIG. 9) and specifies the risk index of the parent node using the risk indices of the child nodes, in accordance with the rule indicated by the data stored in the data field “risk index specifying rule” of the data record of the read-out parent node (step S010).

[0063] Upon specifying the risk index in step S010, estimation means 133 adds a new data record to the risk index log table corresponding to the node ID stored in the data field “node ID” of the data record read out in step S010, stores data indicating the current time in the data field “time” of the added data record, and stores the risk index specified in step S010 in the data field “risk index” (step S011). Accordingly, risk indices indicating the likelihood of occurrence of incidents corresponding to the nodes are specified for all of the nodes shown in the cause-effect relationship tree diagram (FIG. 9).

[0064] If multiple pieces of cause-effect relationship data for one ship 9 are stored in storage means 132, estimation means 133 performs processing in accordance with the flow shown in FIG. 11 for each of the multiple pieces of cause-effect relationship data. Also, if multiple ships 9 are managed by system 1, estimation means 133 performs processing in accordance with the flow shown in FIG. 11 for each of the pieces of cause-effect relationship data stored in storage means 132 for each of multiple ships 9. Estimation means 133 has been described above.

[0065] Description of the configuration of server apparatus 13 will be continued with reference to FIG. 6. Specifying means 134 is constituted mainly by processor 102, and specifies the incident that contributes the most to increasing the likelihood of the occurrence of an

incident (trouble) corresponding to a root node subjected to estimation by estimation means 133 if the likelihood of occurrence of the incident (trouble) exceeds a predetermined threshold value.

[0066] For example, if the risk index specified by estimation means 133 exceeds the predetermined threshold for node N1, the node that contributes the most to the increase in the risk index of node N1 among the child nodes of node N1 (node N11, etc.) is specified. For example, if the risk index specifying rule of node N1 is a weighted average, specifying means 134 specifies the node for which the value that is the product of the risk index and the weight is the largest among the child nodes of node N1 is specified as the node that contributes the most to the increase in the risk index of node N1. Hereinafter, the node specified in this manner will be referred to as a “node of interest”.

[0067] Next, specifying means 134 specifies the node that contributes the most to the increase in the risk index of the node of interest among the child nodes of the node of interest specified as described above, as the node of interest one layer down. Specifying means 134 repeats the processing for specifying the mode of interest one layer down from among the child nodes of the mode of interest until the mode of interest is specified from the leaf nodes.

[0068] Notification means 135 is constituted mainly by processor 102 and communication IF 103 and performs processing for performing notification of the risk indices specified by estimation means 133, the nodes of interest specified by specifying means 134, and the like to the user of terminal apparatus 14 or terminal apparatus 15. Specifically, in response to a request transmitted from terminal apparatus 14 or terminal apparatus 15, notification means 135 generates data indicating a screen for displaying the risk indices specified by estimation means 133, nodes of interest specified by specifying means 134, and the like, as the

notification data, and transmits the notification data to the terminal apparatus that transmitted the request. The configuration of server apparatus 13 has been described above.

[0069] FIG. 13 is a diagram showing a functional configuration of terminal apparatus 14 and terminal apparatus 15. That is, computer 20, which constitutes the hardware of terminal apparatus 14 or terminal apparatus 15, operates as an apparatus that includes the constituent units shown in FIG. 13 by executing data processing in accordance with a program for terminal apparatus 14 or terminal apparatus 15. Hereinafter, the constituent units of terminal apparatus 14 and terminal apparatus 15 shown in FIG. 13 will be described.

[0070] Request means 141 is constituted mainly by communication IF 203, and transmits request data requesting notification data to server apparatus 13 in response to a user operation. Acquisition means 142 is constituted mainly by communication IF 203 and operation apparatus 205, acquires data indicating the user operation, and receives notification data transmitted from server apparatus 13 as a response to the request data transmitted by request means 141.

[0071] Storage means 143 is constituted mainly by memory 201 and stores the notification data received by acquisition means 142. Display means 144 is constituted mainly by processor 202 and display apparatus 204, uses the notification data stored in storage means 143 to generate a screen (hereinafter referred to as “trouble occurrence risk display screen”) for performing notification of the risk indices and the like to the user, and displays the generated trouble occurrence risk display screen.

[0072] FIG. 14 is a diagram showing a trouble occurrence risk display screen. Tables T1 and T2 are included on the left side of the trouble occurrence risk display screen, and graphs G1 and G2 are included on the right side.

Table T1 is a table for selecting ship 9 whose risk indices and the like the user wants to know, from among one or more ships 9 managed by system 1. Table T1 has a "ship name" column and an "alert" column. The ship name of ship 9 is displayed in the "ship name" column. If the risk index of any incident exceeds a predetermined threshold value for prompting caution for a corresponding ship 9, "Yes" is displayed in the "alert" column; otherwise, "No" is displayed. The user can select ship 9 by performing clicking or the like on any row displayed in table T1.

[0073] Table T2 is a table for displaying a list of risk indices for trouble relating to ship 9 selected by the user in table T1. Table T2 has a "caution/warning" column, an "incident name" column, and a "risk index" column. One of "normal", "caution", and "warning" is displayed in the "caution/warning" column. "Normal" indicates that the risk index is less than or equal to a predetermined threshold value for prompting caution. "Caution" indicates that the risk index exceeds the predetermined threshold value for prompting caution but is less than or equal to a threshold value for warning. "Warning" indicates that the risk index value exceeds the predetermined threshold value for warning.

[0074] The name of the trouble is displayed in the "incident name" column. The risk index is displayed in the "risk index" column. The incidents displayed in table T2 are sorted in order of the size of the risk index. The user can perform selection by performing clicking or the like on any row displayed in table T2.

[0075] Graph G1 is a cause-effect relationship tree diagram relating to an incident selected by the user in table T2. If an incident for which "caution" or "warning" is displayed in the "caution/warning" column in table T2 is selected by the user, the node of interest specified by specifying means 134 is displayed in a mode different from that of the other nodes in graph G1. In the example shown in FIG. 14, the nodes

indicated by rectangular shapes surrounded by thicker frames than the other nodes are nodes of interest. Also, the risk indices are displayed in the rectangular shapes indicating the nodes. When the user performs an operation of moving a cursor over any of the nodes, for example, the incident name (node name) corresponding to the rectangular shape subjected to the operation is displayed as a pop-up.

[0076] Graph G2 is a graph showing change over time in the risk index of a type of trouble selected by the user in table T2. Also, the user can select any leaf node displayed in graph G1 by performing clicking or the like. When selection of a leaf node is performed by the user, a graph showing the temporal change in the attribute value used to calculate the risk index of the selected leaf node is subjected to pop-up display. FIG. 15 is a diagram illustrating a graph subjected to pop-up display in this manner.

[0077] According to system 1 described above, by viewing the trouble occurrence risk display screen displayed on terminal apparatus 14 or terminal apparatus 15, the user can easily find out the likelihood of occurrence of trouble in ship 9. Also, if the likelihood of occurrence of trouble has become high, the user can easily find out the incident that is the cause of the increase in the likelihood of the occurrence of trouble. Accordingly, the user can take a countermeasure for preventing the occurrence of trouble.

[0078] [Modifications]

The above-described embodiment can be modified in various ways within the scope of the technical idea of the present invention. Hereinafter, examples of these modifications will be shown.

[0079] (1) Server apparatus 13 may also be arranged on ship 9. If server apparatus 13 is arranged on ship 9, server apparatus 12 and server apparatus 13 may also be integrated into one apparatus.

[0080] (2) An attribute value that is not an attribute value measured on ship 9 may also be used as the attribute value to be used by estimation means 133 of server apparatus 13 to specify the risk index. For example, server apparatus 13 may also acquire data indicating atmospheric incidents and maritime incidents (wind direction, wind speed, etc.) in a water zone through which ship 9 navigates from a server apparatus that provides information on atmospheric incidents and maritime incidents, and server apparatus 13 may also use the atmospheric incidents and maritime incidents indicated by the acquired data to specify the risk index.

[0081] (3) The number of attributes used by estimation means 133 of server apparatus 13 to specify the risk index of a leaf node in the cause-effect relationship tree diagram is not limited. For example, the risk index of the leaf node may also be specified using one type of attribute value, and the risk index of the leaf node may also be specified using two or more types of attribute values.

[0082] (4) The above-described risk index specifying rules are merely examples, and various rules are used to specify the risk indices. For example, in the above description of the embodiment, as a risk index specifying rule using the graph shown in FIG. 7, a rule was given as an example, in which a value obtained by multiplying distance D in the y-axis direction between line M, which is a reference line, and a point indicating a combination of measured attribute values, by a constant # is used as the risk index. Instead of distance D, the measured probability of occurrence for the main engine load and the average cylinder exhaust gas temperature may also be used to specify the risk index. In this case, for example, for various main engine loads, the user of terminal apparatus 14 estimates a probability distribution (e.g., regular distribution) of a population of samples that are the average cylinder

exhaust gas temperatures measured when the main engine load was measured for various main engine loads, and stores data indicating the estimated probability distribution in storage unit 132. In the specifying of the risk index, estimation means 133 reads out data indicating the probability distribution corresponding to the measured main engine load from storage means 132, and specifies the occurrence probability of the measured average cylinder exhaust gas temperature as the risk index in accordance with the probability distribution indicated by the read-out data. In this manner, the occurrence probability of the measured attribute value (or combination of attribute values) may be used to specify the risk index.

[0083] (5) In the above-described embodiment, transfer of the data between apparatuses such as server apparatus 12 and server apparatus 13 is performed through transmission and reception of data via a network. The method for transferring the data between these apparatuses is not limited to transmitting and receiving data via a network. For example, while ship 9 is performing navigation, transfer of the attribute value data from server apparatus 12 to server apparatus 13 may also be performed not by transferring the attribute value data acquired by acquisition means 121 to server apparatus 13, but by accumulating the attribute value data in storage means 122, copying the attribute value data accumulated in storage means 122 to a storage medium while ship 9 is anchored at a port, and causing server apparatus 13 to load the attribute value data from the storage medium.

[0084] (6) In the above-described embodiment, the risk index is compared with a predetermined threshold value and the likelihood of occurrence of an incident is evaluated for only incidents corresponding to root nodes of the cause-effect relationship tree diagram. The incidents for which server apparatus 12 performs evaluation of the likelihood of occurrence

are not limited to incidents corresponding to the root nodes, and the likelihood of occurrence may also be evaluated for incidents corresponding to internal nodes. In this case, for example, various types of information corresponding to the internal nodes may also be displayed using a screen similar to the screen illustrated in FIG. 14 for the incidents corresponding to root nodes.

[0085] (7) In the above-described embodiment, server apparatus 12, server apparatus 13, terminal apparatus 14, and terminal apparatus 15 are realized by a general computer executing processing in accordance with a program. Instead of this, at least a portion of server apparatus 12, server apparatus 13, terminal apparatus 14, and terminal apparatus 15 may be constituted as a so-called dedicated apparatus.

[0086] (8) The program according to the present invention, that is, the program illustrated as the program that is executed by computer 10 to realize server apparatus 12 or server 13, or the program illustrated as the program executed by computer 20 to realize terminal apparatus 14 or terminal apparatus 15 may also be provided in a state of being stored in a computer-readable storage medium such as an optical storage medium or a semiconductor memory, and may also be provided via a communication network such as the Internet. If the program according to the present invention is provided in a state of being stored in a storage medium, computer 10 or computer 20 reads out the program from the storage medium and uses the program. Also, if the program according to the present invention is provided via a communication network, computer 10 or computer 20 receives the program from an apparatus that is a distribution source and uses the program.

DESCRIPTION OF REFERENCE NUMERALS

[0087] 1 … System, 8 … Communication satellite, 9 … Ship, 10 … Computer,

11 … Measurement apparatus group, 12 … Server apparatus, 13 … Server apparatus, 14 … Terminal apparatus, 15 … Terminal apparatus, 20 … Computer, 101 … Memory, 102 … Processor, 103 … Communication IF, 121 … Acquisition means, 122 … Storage means, 123 … Transmission means, 131 … Acquisition means, 132 … Storage means, 133 … Estimation means, 134 … Specifying means, 135 … Notification means, 141 … Request means, 142 … Acquisition means, 143 … Storage means, 144 … Display means, 201 … Memory, 202 … Processor, 203 … Communication IF, 204 … Display apparatus, 205 … Operation apparatus

CLAIMS

[Claim 1]

An apparatus comprising:

an acquisition means for acquiring cause-effect relationship data indicating a cause-effect relationship between a plurality of incidents that occur in a ship and indicating rules for estimating an index indicating a likelihood of occurrence of each of the plurality of the incidents in the future, and attribute value data indicating, for each of one or more incidents for which an incident serving as a cause is not indicated by the cause-effect relationship data, an attribute value of the ship or an environment in which the ship is located, relating to an occurrence of the incident; and

an estimation means for estimating an index indicating a likelihood of occurrence in the future in accordance with the attribute value indicated by the attribute value data regarding each of one or more incidents for which an incident serving as a cause is not indicated by the cause-effect relationship data, and for estimating an index indicating a likelihood of occurrence in the future in accordance with the rule indicating the cause-effect relationship data by the index estimating the incident serving as a cause of the incident regarding each of one or more incidents for which an incident serving as a cause is indicated by the cause-effect relationship data.

[Claim 2]

The apparatus comprising:

an acquisition means for acquiring cause-effect relationship data

indicating a cause-effect relationship between a plurality of incidents that occur in a ship, and attribute value data indicating, for each of one or more incidents for which an incident serving as a cause is not indicated by the cause-effect relationship data, an attribute value of the ship or an environment in which the ship is located, relating to an occurrence of the incident; and

an estimation means for estimating a likelihood of occurrence of each of the plurality of incidents based on the cause-effect relationship data and the attribute value data, wherein

for each of the one or more incidents for which an incident serving as a cause is not indicated by the cause-effect relationship data, the acquisition means acquires reference value data indicating a reference value of an attribute value of the ship or the environment in which the ship is located, relating to the incident, and

for each of the one or more incidents for which an incident serving as a cause is not indicated by the cause-effect relationship data, the estimation means estimates the likelihood of occurrence of the incident based on the result of comparing an attribute value indicated by the attribute value data relating to the incident and a reference value indicated by the reference value data relating to the incident.

[Claim 3]

The apparatus comprising:

an acquisition means for acquiring cause-effect relationship data indicating a cause-effect relationship between a plurality of incidents that occur in a ship, and attribute value data indicating, for each of one or more incidents for which an incident serving as

a cause is not indicated by the cause-effect relationship data, an attribute value of the ship or an environment in which the ship is located, relating to an occurrence of the incident; and

an estimation means for estimating a likelihood of occurrence of each of the plurality of incidents based on the cause-effect relationship data and the attribute value data, wherein

for each of at least one of the one or more incidents for which an incident serving as a cause is not indicated by the cause-effect relationship data, the acquisition means acquires the attribute value data indicating a plurality of attribute values of the ship or the environment in which the ship is located, relating to the incident,

for each of the at least one incident, the acquisition means acquires reference value data indicating a reference combination of a plurality of attribute values relating to the incident, and

for each of the at least one incident, the estimation means estimates the likelihood of occurrence of the incident based on the result of comparing the combination of the plurality of attribute values indicated by the attribute value data and the reference combination of the plurality of attribute values indicated by the reference value data.

[Claim 4]

The apparatus according to any one of claims 1 to 3, wherein

the cause-effect relationship data indicates a tree structure in which the plurality of incidents are nodes, and a contribution level according to which, in each node group in a parent-child relationship in the tree structure, the likelihood of occurrence of an incident of a child node included in the node group contributes to

the likelihood of occurrence of an incident of a parent node included in the node group, and

for each of one or more leaf nodes in the tree structure, the estimation means estimates the likelihood of occurrence of an incident of the leaf node based on the attribute value data relating to the incident of the leaf node, and estimates the likelihood of occurrence of an incident of an internal node in the tree structure in order from a leaf node side to a root node side based on the estimated likelihood of occurrence of the incident of the leaf node and the contribution level indicated by the cause-effect relationship data.

[Claim 5]

The apparatus according to any one of claims 1 to 4, comprising:

a notification means for performing processing for performing notification of the incident to a user if the likelihood of occurrence estimated by the estimation means exceeds a predetermined threshold value.

[Claim 6]

The apparatus according to claim 5, comprising:

a specifying means for specifying the incident that contributes the most to an increase in the likelihood of occurrence of an incident for which the likelihood of occurrence estimated by the estimation means exceeds a predetermined threshold value,

wherein the notification means performs processing for performing notification of the incident specified by the specifying means to the

user.

[Claim 7]

A program for causing a computer to execute:

processing for acquiring cause-effect relationship data indicating a cause-effect relationship between a plurality of incidents that occur in a ship and indicating rules for estimating an index indicating a likelihood of occurrence of each of the plurality of the incidents in the future, and attribute value data indicating, for each of one or more incidents for which an incident serving as a cause is not indicated by the cause-effect relationship data, an attribute value of the ship or an environment in which the ship is located, relating to an occurrence of the incident; and

processing for estimating an index indicating a likelihood of occurrence in the future in accordance with the attribute value indicated by the attribute value data regarding each of one or more incidents for which an incident serving as a cause is not indicated by the cause-effect relationship data, and for estimating an index indicating a likelihood of occurrence in the future in accordance with the rule indicating the cause-effect relationship data by the index estimating the incident serving as a cause of the incident regarding each of one or more incidents for which an incident serving as a cause is indicated by the cause-effect relationship data.

[Claim 8]

A program for causing a computer to execute:

processing for acquiring cause-effect relationship data indicating a

cause-effect relationship between a plurality of incidents that occur in a ship, and attribute value data indicating, for each of one or more incidents for which an incident serving as a cause is not indicated by the cause-effect relationship data, an attribute value of the ship or an environment in which the ship is located, relating to an occurrence of the incident; and

processing for estimating a likelihood of occurrence of each of the plurality of incidents based on the cause-effect relationship data and the attribute value data, wherein

for each of the one or more incidents for which an incident serving as a cause is not indicated by the cause-effect relationship data, the estimation means estimates the likelihood of occurrence of the incident based on the result of comparing an attribute value indicated by the attribute value data relating to the incident and a reference value indicated by the reference value data relating to the incident.

[Claim 9]

An apparatus comprising:

an acquisition means for acquiring cause-effect relationship data indicating a cause-effect relationship between a plurality of incidents that occur in a ship, and attribute value data indicating, for each of one or more incidents for which an incident serving as a cause is not indicated by the cause-effect relationship data, an attribute value of the ship or an environment in which the ship is located, relating to an occurrence of the incident; and

an estimation means for estimating a likelihood of occurrence of each of the plurality of incidents based on the cause-effect

relationship data and the attribute value data, wherein

for each of the one or more incidents, the estimation means estimates the likelihood of occurrence of the incident based on the result of comparing the combination of the plurality of attribute values indicated by the attribute value data and the reference combination of the plurality of attribute values indicated by the reference value data.

[Claim 10]

A computer-readable storage medium permanently storing a program for causing a computer to execute:

processing for acquiring cause-effect relationship data indicating a cause-effect relationship between a plurality of incidents that occur in a ship and indicating rules for estimating an index indicating a likelihood of occurrence of each of the plurality of the incidents in the future, and attribute value data indicating, for each of one or more incidents for which an incident serving as a cause is not indicated by the cause-effect relationship data, an attribute value of the ship or an environment in which the ship is located, relating to an occurrence of the incident; and

processing for estimating an index indicating a likelihood of occurrence in the future in accordance with the attribute value indicated by the attribute value data regarding each of one or more incidents for which an incident serving as a cause is not indicated by the cause-effect relationship data, and for estimating an index indicating a likelihood of occurrence in the future in accordance with the rule indicating the cause-effect relationship data by the index estimating the incident serving as a cause of the incident

regarding each of one or more incidents for which an incident serving as a cause is indicated by the cause-effect relationship data.

[Claim 11]

A computer-readable storage medium permanently storing a program for causing a computer to execute:

processing for acquiring cause-effect relationship data indicating a cause-effect relationship between a plurality of incidents that occur in a ship, and attribute value data indicating, for each of one or more incidents for which an incident serving as a cause is not indicated by the cause-effect relationship data, an attribute value of the ship or an environment in which the ship is located, relating to an occurrence of the incident; and

processing for estimating a likelihood of occurrence of each of the plurality of incidents based on the cause-effect relationship data and the attribute value data, wherein

for each of the one or more incidents for which an incident serving as a cause is not indicated by the cause-effect relationship data, the estimation means estimates the likelihood of occurrence of the incident based on the result of comparing an attribute value indicated by the attribute value data relating to the incident and a reference value indicated by the reference value data relating to the incident.

[Claim 12]

A computer-readable storage medium permanently storing a program for causing a computer to execute:

an acquisition means for acquiring cause-effect relationship data indicating a cause-effect relationship between a plurality of incidents that occur in a ship, and attribute value data indicating, for each of one or more incidents for which an incident serving as a cause is not indicated by the cause-effect relationship data, an attribute value of the ship or an environment in which the ship is located, relating to an occurrence of the incident; and

an estimation means for estimating a likelihood of occurrence of each of the plurality of incidents based on the cause-effect relationship data and the attribute value data, wherein

for each of the one or more incidents, the estimation means estimates the likelihood of occurrence of the incident based on the result of comparing the combination of the plurality of attribute values indicated by the attribute value data and the reference combination of the plurality of attribute values indicated by the reference value data.