DESCRIPTION

Title of Invention: SHIP MANEUVERING SUPPORTING SYSTEM

Technical Field

[0001] The present invention relates to a ship maneuvering supporting system that is used in assisting a subject ship by at least one tugboat.

Background Art

[0002] For example, in a port, it is often the case that a ship is assisted by at least one tugboat (hereinafter, a ship assisted by at least one tugboat is referred to as "subject ship"). In some cases, the subject ship may be a ship that includes at least one thruster and that is capable of traveling by itself. In other cases, the subject ship may be a ship that includes no thruster, or may be a ship that is incapable of traveling by itself due to its failed thruster.

[0003] Generally speaking, in a port, a conductor, such as a maritime pilot or the captain of the subject ship, conducts how to maneuver the subject ship and/or the tugboat. Examples of the manner of assisting the subject ship by the tugboat include pushing the subject ship by the tugboat, towing the subject ship by the tugboat, and causing the tugboat to travel alongside the subject ship. The conductor gives instructions to the tugboat, as necessary, about which manner of assistance to use.

[0004] For example, Patent Literature 1 discloses a portable tugboat instruction device with a screen. The screen displays a ship-shaped symbol and arrow symbols. The ship-shaped symbol represents a subject ship. The arrow symbols represent respective tugboats, and indicate the positions of the respective tugboats relative to the subject ship as well as the azimuths of the respective tugboats relative to the subject ship. Therefore, a person who looks at the screen can recognize whether the tugboats are to push or to tow the subject ship, and can also recognize their positions and directions.

Citation List

Patent Literature

[0005] PTL 1: Japanese Laid-Open Utility Model Application Publication No. S61-105298

Summary of Invention

Technical Problem

[0006] However, the tugboat instruction device disclosed by Patent Literature 1 merely displays, on the screen, the arrow symbols that indicate the positions and the azimuths of the

respective tugboats relative to the subject ship. Therefore, the person looking at the screen cannot clearly recognize how the subject ship is to move.

[0007] In view of the above, an object of the present invention is to provide a ship maneuvering supporting system that allows a person who looks at the screen of a display to clearly recognize the movement of a subject ship.

Solution to Problem

[0008] In order to solve the above-described problems, a ship maneuvering supporting system according to one aspect of the present invention is a ship maneuvering supporting system that is used in assisting a subject ship including at least one thruster by at least one tugboat, the ship maneuvering supporting system including: at least one display including a screen; and a controller that obtains subject ship position and azimuth information about a position and an azimuth of the subject ship and tugboat position and azimuth information about a position and an azimuth of the at least one tugboat, and displays a subject ship profile line and at least one tugboat profile line on the screen, the subject ship profile line indicating the position and the azimuth of the subject ship, the at least one tugboat profile line indicating the position and the azimuth of the at least one tugboat. The controller calculates a target propulsion vector of the at least one thruster of the subject ship and a target propulsion vector of the at least one tugboat, and displays the target propulsion vector of the at least one thruster of the subject ship and the target propulsion vector of the at least one tugboat on the screen.

[0009] According to the above configuration, not only the target propulsion vector of the tugboat, but also the target propulsion vector of the thruster of the subject ship is displayed on the screen. Therefore, a person who looks at the screen of the display can take the thrust of the thruster of the subject ship into consideration, and can clearly recognize the movement of the subject ship.

[0010] A ship maneuvering supporting system according to another aspect of the present invention is a ship maneuvering supporting system that is used in assisting a subject ship by at least one tugboat, the ship maneuvering supporting system including: at least one display including a screen; and a controller that obtains subject ship position and azimuth information about a position and an azimuth of the subject ship and tugboat position and azimuth information about a position and an azimuth of the at least one tugboat, and displays a subject ship profile line and at least one tugboat profile line on the screen, the subject ship profile line indicating the position and the azimuth of the subject ship, the at least one tugboat profile line indicating the position and the azimuth of the at least one tugboat. The controller calculates a predicted

position and a predicted azimuth of the subject ship after an elapse of a predetermined time, and displays a subject ship predicted profile line indicating the predicted position and the predicted azimuth on the screen.

[0011] According to the above configuration, a person who looks at the screen of the display can imagine changes that will occur in the position and the azimuth of the subject ship until the elapse of the predetermined time. Therefore, the person who looks at the screen of the display can clearly recognize the movement of the subject ship.

[0012] A ship maneuvering supporting system according to yet another aspect of the present invention is a ship maneuvering supporting system that is used in assisting a subject ship by tugboats, the ship maneuvering supporting system including: at least one display including a screen; and a controller that obtains subject ship position and azimuth information about a position and an azimuth of the subject ship and tugboat position and azimuth information about positions and azimuths of the respective tugboats, and displays a subject ship profile line and tugboat profile lines on the screen, the subject ship profile line indicating the position and the azimuth of the subject ship, the tugboat profile lines indicating the positions and the azimuths of the respective tugboats. The controller calculates a planned propulsion vector of the subject ship and a planned turning moment of the subject ship, the planned propulsion vector being on a straight line passing through a pivot point of the subject ship, the planned turning moment being a moment about the pivot point, and displays the planned propulsion vector and the planned turning moment on the screen.

[0013] According to the above configuration, the movement of the subject ship with respect to the pivot point is visualized. Therefore, a person who looks at the screen of the display can clearly recognize the movement of the subject ship.

Advantageous Effects of Invention

[0014] According to the present invention, a person who looks at the screen of the display can clearly recognize the movement of the subject ship.

Brief Description of Drawings

[0015] FIG. 1 shows a schematic configuration of a ship maneuvering supporting system according to Embodiment 1 of the present invention.

FIG. 2 shows one example of a screen of a display of a terminal in the ship maneuvering supporting system.

FIG. 3 shows a schematic configuration of the terminal.

FIG. 4 is a drawing for describing one ship maneuvering pattern.

FIG. 5 is a drawing for describing another ship maneuvering pattern.

FIG. 6 is a drawing for describing yet another ship maneuvering pattern.

FIG. 7 shows a variation of the screen of the display.

FIG. 8 shows another variation of the screen of the display.

FIG. 9 shows a schematic configuration of the terminal in a ship maneuvering supporting system according to Embodiment 2 of the present invention.

FIG. 10 is a plan view of a second inputter.

FIG. 11 shows one example of the screen of the display in a case where a subject ship includes no thruster.

FIG. 12 shows a variation of the screen of the display.

Description of Embodiments

[0016] (Embodiment 1)

FIG. 1 shows a ship maneuvering supporting system 4 according to Embodiment 1 of the present invention. The ship maneuvering supporting system 4 is used in assisting a subject ship 1 by at least one tugboat 2. FIG. 1 illustratively shows a case where the number of tugboats 2 is two.

[0017] The present embodiment assumes that assisting the subject ship 1 by the tugboat(s) 2 is performed in a port. Alternatively, assisting the subject ship 1 by the tugboat(s) 2 may be performed on the open ocean. In the present embodiment, the ship maneuvering supporting system 4 includes a terminal 3, which is independent of the subject ship 1 and the at least one tugboat 2. The terminal 3 is carried by a maritime pilot, or installed in an on-land facility. The present embodiment further assumes that the subject ship 1 and the at least one tugboat 2 are manned vehicles.

[0018] A controller 11, a display 12 (corresponding to a subject ship display of the present invention), and a communicator 13 are installed in the subject ship 1. Similarly, a controller 21, a display 22 (a tugboat display of the present invention), and a communicator 23 are installed in the at least one tugboat 2. These devices, together with the terminal 3, form the ship maneuvering supporting system 4. For example, the controller 11 and the display 12 of the subject ship 1 are incorporated in a bridge console of the subject ship 1, and the controller 21 and the display 22 of the tugboat 2 are incorporated in a bridge console of the tugboat 2.

[0019] As shown in FIG. 1 and FIG. 3, the terminal 3 includes an inputter 35, a controller 31, a display 32 (corresponding to a terminal display of the present invention), and a

communicator 33. For example, the terminal 3 may be a portable tablet computer, or may be a laptop computer.

[0020] For example, the controller 31 includes memories such as a ROM and RAM, a storage such as a HDD, and a CPU. The CPU executes a program stored in the ROM or HDD. The controller 11 installed in the subject ship 1 and the controller 21 installed in the at least one tugboat 2 are also configured in the same manner as the controller 31.

[0021] In the present embodiment, the controller 31 of the terminal 3 sets a ship maneuvering pattern and so forth, the ship maneuvering pattern including a manner of assisting the subject ship 1 by the at least one tugboat 2. This will be described in detail. Accordingly, as shown in FIG. 3, the controller 31 includes a database 34, which contains various information.

[0022] Alternatively, the ship maneuvering pattern and so forth may be set by the controller 11 installed in the subject ship 1, or by the controller 21 installed in one tugboat 2. In this case, the database 34 may be included in the controller (11 or 21) that sets the ship maneuvering pattern. Alternatively, also in the case where the ship maneuvering pattern is set by the controller 11 installed in the subject ship 1 or by the controller 21 installed in one tugboat 2, the database 34 may be included in the controller 31 of the terminal 3, and information contained in the database 34 may be transmitted by below-described wireless communication to the controller (11 or 21) that sets the ship maneuvering pattern.

[0023] The communicator 33 of the terminal 3 can communicate, by wireless communication, with the communicator 13 of the subject ship 1 and the communicator 23 of the at least one tugboat 2. The wireless communication may be communication that is performed via AIS (Automatic Identification System), or may be communication that is directly performed between ships, or may be ship-land intercommunication that is performed via a ground base station.

[0024] The controller 11 of the subject ship 1 stores, in real time, subject ship position and azimuth information about the position and the azimuth of the subject ship 1. The position of the subject ship 1 is measured by GNSS (Global Navigation Satellite System), and the azimuth of the subject ship 1 is measured by an azimuth meter provided in the subject ship 1. The subject ship position and azimuth information is transmitted from the communicator 13 of the subject ship 1 to the communicator 33 of the terminal 3.

[0025] The controller 21 of the at least one tugboat 2 stores, in real time, tugboat position and azimuth information about the position and the azimuth of the tugboat 2. The position of the tugboat 2 is measured by GNSS, and the azimuth of the tugboat 2 is measured by an azimuth meter provided in the tugboat 2. The tugboat position and azimuth information about the at

least one tugboat 2 is transmitted from the communicator 23 of the tugboat 2 to the communicator 33 of the terminal 3.

[0026] The controller 31 of the terminal 3 obtains the above-described subject ship position and azimuth information and tugboat position and azimuth information via the communicator 33.

[0027] With the inputter 35, a user inputs subject ship via point information that includes a departure point and a destination point of the subject ship 1. As a result of the user making the input, the controller 31 obtains the subject ship via point information. For example, the inputter 35 may be a touch panel or a keyboard.

[0028] The subject ship via point information includes not only the position of the departure point, but also the azimuth and the speed of the subject ship 1 at the departure point. Similarly, the subject ship via point information includes not only the position of the destination point, but also the azimuth and the speed of the subject ship 1 at the destination point. The subject ship via point information may include a middle point (the position of the middle point as well as the azimuth and the speed of the subject ship 1 at the middle point).

[0029] The controller 31 further obtains environmental information including weather information such as wind information about the wind in the port and/or oceanographic phenomenon information such as wave information and tide information about the wave and tide in the port. For example, the controller 31 obtains the environmental information from an outside agency, such as the meteorological agency or NOAA (National Ocean and Atmospheric Administration) via the communicator 33 and the Internet. Alternatively, the controller 31 may obtain the wind information of the environmental information from an anemometer installed in the subject ship 1.

[0030] The database 34 contains subject ship information about the specifications of the subject ship 1, combination information about the number of tugboats set in accordance with the subject ship information, and tugboat information about the specifications of the at least one tugboat 2. The specifications of the subject ship 1 are, for example, the shape, the weight, and the draft of the subject ship 1, the number of thrusters of the subject ship 1, the position(s) and performance of the thruster(s), and a position or positions on the ship 1, to which the tugboat(s) is/are connectable.

[0031] The number of tugboats 2 used in assisting the subject ship 1 is preset in accordance with, for example, the type of the subject ship 1, port rules, and oceanographic conditions. The combination information is information about the number of tugboats 2. The specifications of the tugboat 2 are, for example, the shape of the tugboat 2, the number of thrusters of the tugboat 2, and the performance of the thruster(s).

[0032] Each time the subject ship 1 enters the port, the information contained in the database 34 may be updated into information relating to the subject ship 1 (the subject ship information, the combination information, and the tugboat information). Alternatively, information about all of the subject ships 1 that are expected to enter the port may be contained in the database 34 in advance.

[0033] As shown in FIG. 2, based on the obtained subject ship position and azimuth information and tugboat position and azimuth information, the controller 31 displays a subject ship profile line 10 and at least one tugboat profile line 20 on the screen of the display 32. The subject ship profile line 10 indicates the position and the azimuth of the subject ship 1. The at least one tugboat profile line 20 indicates the position and the azimuth of the at least one tugboat 2.

[0034] For example, the subject ship profile line 10 is a polygonal (in FIG. 2, pentagonal) profile line that resembles the shape of the subject ship 1, and the tugboat profile line 20 is a polygonal (in FIG. 2, triangular) profile line that resembles the shape of the tugboat 2.

[0035] In the present embodiment, the controller 31 sets the ship maneuvering pattern as described above. In a case where the tugboat 2 tows the subject ship 1, the controller 31 also displays a tag line 15 on the screen of the display 32. The tag line 15 connects between the subject ship 1 and the tugboat 2.

[0036] The above-described database 34 may contain land information that includes the shape of a quay wall 61. In this case, the controller 31 reads out the land information from the database 34, and when the position of the subject ship 1 is close to the quay wall 61, the controller 31 displays the quay wall 61 on the screen of the display 32.

[0037] In the present embodiment, the controller 31 calculates a planned propulsion vector 53 of the subject ship 1 and a planned turning moment 54 of the subject ship 1. The planned propulsion vector 53 is on a straight line passing through a pivot point 51 of the subject ship 1, and the planned turning moment 54 is a moment about the pivot point 51. Accordingly, the controller 31 also displays the pivot point 51, the calculated planned propulsion vector 53, and the calculated planned turning moment 54 on the screen of the display 32.

[0038] In the example shown in FIG. 2, the planned propulsion vector 53 is displayed as a linear arrow whose start point is the pivot point 51. Alternatively, the planned propulsion vector 53 may be displayed as an arrow whose start point is away from the subject ship profile line 10. Further alternatively, the planned propulsion vector 53 may be displayed not as an arrow, but as an elongated triangle, or may be displayed as triangles arranged on a single straight line (in this case, the number of triangles represents the magnitude of the vector). The direction

and the magnitude of the planned propulsion vector 53 may be displayed as a character and a number. The same applies to the displaying of other vectors described below.

[0039] In the example shown in FIG. 2, the planned turning moment 54 is displayed as an arrow that is arc-shaped about the pivot point 51 of the subject ship 1. However, the planned turning moment 54 need not be displayed as an arrow. For example, the direction and the magnitude of the planned turning moment 54 may be displayed, for example, as a character and a number.

[0040] Further, in the present embodiment, the subject ship 1 includes at least one thruster, and the controller 31 calculates a target propulsion vector of the at least one thruster of the subject ship 1 and a target propulsion vector of the at least one tugboat 2. Accordingly, the controller 31 displays, on the screen of the display 32, the calculated target propulsion vector of the at least one thruster of the subject ship 1 and the calculated target propulsion vector of the at least one tugboat 2.

[0041] The target propulsion vector of the at least one thruster of the subject ship 1 and the target propulsion vector of the at least one tugboat 2 are results of resolving the above-described planned propulsion vector 53 and planned turning moment 54 of the subject ship 1. In other words, the planned propulsion vector 53 and the planned turning moment 54 of the subject ship 1 are results of synthesizing the target propulsion vector of the at least one thruster of the subject ship 1 and the target propulsion vector of the at least one tugboat 2.

[0042] At the time of resolving the planned turning moment 54, the planned turning moment 54 is converted into a force that is on a straight line that passes through a point of application of force of the tugboat 2 on the subject ship 1 (i.e., a point at which the subject ship 1 is pushed or towed by the tugboat 2), the straight line touching a circle whose center is the pivot point 51 of the subject ship 1, the straight line extending in the pushing direction or towing direction of the tugboat 2.

[0043] FIG. 2 shows one example of the screen of the display 32 in a case where the subject ship 1 includes a main thruster 1a, a rudder 1b, and a side thruster 1c as shown in FIG. 4 to FIG. 6. In the example shown in FIG. 2, the subject ship 1 is assisted by three tugboats 2. One of the three tugboats 2 pushes the subject ship 1, and the other two tugboats 2 tow the subject ship 1 via the tag line 15.

[0044] In the example shown in FIG. 2, a target propulsion vector 71 of the main thruster 1a of the subject ship 1 is displayed as an arrow whose start point is the position of the main thruster 1a within the subject ship profile line 10, and a target propulsion vector 72 of the side thruster 1c of the subject ship 1 is displayed as an arrow whose start point is the position of the side thruster

1c within the subject ship profile line 10. Further, in the example shown in FIG. 2, target propulsion vectors 81 to 83 of the three respective tugboats 2 are each displayed as an arrow whose start point is a center point within the tugboat profile line 20.

[0045] Further, in the present embodiment, the controller 31 calculates a predicted position and a predicted azimuth of the subject ship 1 after the elapse of a predetermined time, and displays a subject ship predicted profile line 55 indicating the calculated predicted position and predicted azimuth on the screen of the display 32.

[0046] Next, processes performed by the controller 31 of the terminal 3 are described with reference to FIG. 3. The processes described below are sequentially performed in real time.

[0047] First, based on the obtained subject ship via point information and environmental information as well as the information contained in the database 34, the controller 31 sets an optimum route of the subject ship 1 and a ship maneuvering pattern including a manner of assisting the subject ship 1 by the at least one tugboat 2. In the present embodiment, as described above, the subject ship 1 includes at least one thruster. Accordingly, the ship maneuvering pattern includes a manner of using the at least one thruster of the subject ship 1.

[0048] FIG. 4 to FIG. 6 show three different ship maneuvering patterns for docking the subject ship 1 to the quay. Each of FIG. 4 and FIG. 6 shows one example in which the subject ship 1 is assisted by two tugboats 2. FIG. 5 shows one example in which the subject ship 1 is assisted by one tugboat 2. In FIG. 4 to FIG. 6, among the thrusters of the subject ship 1 and the tugboats 2, those in use are indicated by solid line, and those not in use are indicated by dashed line.

[0049] In the examples shown in FIG. 4 to FIG. 6, the subject ship 1 includes the main thruster 1a and the side thruster 1c. Also, in the examples shown in FIG. 4 to FIG. 6, the axial direction of the main thruster 1a is unchangeable, and the subject ship 1 includes the rudder 1b. Alternatively, the subject ship 1 need not include the side thruster 1c, and may include only the main thruster 1a. Further alternatively, the rudder 1b may be eliminated, and the axial direction of the main thruster 1a may be changeable.

[0050] In the example shown in FIG. 4, the side thruster 1c is used when the speed of the subject ship 1 has become sufficiently low. Specifically, in the example shown in FIG. 4, at a position far from the quay wall 61, the subject ship 1 can be properly navigated only with the main thruster 1a and the rudder 1b. Therefore, the tugboats 2 travel alongside the subject ship 1. As the subject ship 1 comes closer to the quay wall 61, suitable turning performance and deceleration performance cannot be obtained only with the main thruster 1a and the rudder 1b of the subject ship 1. Therefore, the two tugboats 2 push the subject ship 1 from both sides.

[0051] Thereafter, the main thruster 1a of the subject ship 1 is stopped, causing the subject ship 1 to travel by inertia. When the speed of the subject ship 1 has decreased sufficiently, the two tugboats 2 move their positions to push the subject ship 1 from one side toward the quay wall 61, and while the two tugboats 2 are pushing the subject ship 1 from the one side, the side thruster 1c of the subject ship 1 is used.

[0052] In the example shown in FIG. 5, unlike the example shown in FIG. 4, the rudder 1b of the subject ship 1 is not operated. In the example shown in FIG. 5, when the subject ship 1 has come close to the quay wall 61, one tugboat 2 pushes the subject ship 1 from one side. At the time, the tugboat 2 and the subject ship 1 are connected by the tag line 15.

[0053] Thereafter, the main thruster 1a of the subject ship 1 is stopped, causing the subject ship 1 to travel by inertia. At the time, the tugboat 2 controls the inertial travel and the azimuth of the subject ship 1 while towing the subject ship 1 via the tag line 15.

[0054] In the example shown in FIG. 6, from when the subject ship 1 has come close to the quay wall 61, the two tugboats 2 start towing the subject ship 1 from one side to dock the subject ship 1 to the quay.

[0055] Returning to FIG. 3, the controller 31 first calculates external forces applied to the subject ship 1 (an external force in the fore-aft direction, an external force in the port-starboard direction, and an external force in a turning direction) based on environmental information. Then, the controller 31 sets a ship maneuvering pattern and an optimum route, while determining which manner of assisting the subject ship 1 by the tugboat(s) 2 and which manner of using the at least one thruster of the subject ship 1 (e.g., the main thruster 1a and the side thruster 1c) are most suitable when such external forces are applied to the subject ship 1.

[0056] For example, the controller 31 may assume the subject ship 1 and the at least one tugboat 2 to be one virtual hull, and may set the ship maneuvering pattern and the optimum route so that the required time and fuel consumption can be minimized while avoiding risks, such as the risk of the virtual hull colliding with the quay wall or other ships. Specifically, the controller 31 uses an evaluation function including an evaluation value relating to the energy consumption of the virtual hull and an evaluation value relating to the safety of the virtual hull, and executes an optimal value search algorithm to minimize the evaluation function, thereby setting the ship maneuvering pattern and the optimum route. This makes it possible to set the ship maneuvering pattern and the optimum route so as to secure the safety while suppressing the energy consumption of the virtual hull.

[0057] For example, the controller 31 may calculate a necessary virtual hull thrust for each of the ship maneuvering patterns and routes, and may use, as the evaluation function, a total value

S, which is the total of the following: a rate of change square value V_1 of the virtual hull thrust; a square sum value V_2 of the virtual hull thrust; a first degree of danger evaluation value V_3 corresponding to a distance between the virtual hull and an obstacle such as the quay wall or another ship; and a second degree of danger evaluation value V_4 corresponding to the speed of the virtual hull relative to the obstacle (i.e., the total value $S = V_1 + V_2 + V_3 + V_4$).

[0058] Further, the controller 31 calculates the planned propulsion vector 53 and the planned turning moment 54 of the subject ship 1 for when the subject ship 1 navigates along the optimum route, and displays the calculated planned propulsion vector 53 and the calculated planned turning moment 54 of the subject ship 1 on the screen of the display 32.

[0059] The controller 31 stores subject ship thrust plan information about the calculated planned propulsion vector 53 and the calculated planned turning moment 54 of the subject ship 1. Then, the terminal 3 constructs a server-client system, in which the terminal 3 serves as a server and the subject ship 1 and/or the at least one tugboat 2 serve as a client or clients.

[0060] That is, the controller 11 of the subject ship 1 can obtain the subject ship thrust plan information from the terminal 3. When the controller 11 obtains the subject ship thrust plan information, the controller 31 of the terminal 3 displays the planned propulsion vector 53 and the planned turning moment 54 of the subject ship 1 on the screen of the display 12 via the controller 11 of the subject ship 1.

[0061] Similarly, the controller 21 of the at least one tugboat 2 can obtain the subject ship thrust plan information from the terminal 3. When the controller 21 obtains the subject ship thrust plan information, the controller 31 of the terminal 3 displays the planned propulsion vector 53 and the planned turning moment 54 of the subject ship 1 on the screen of the display 22 via the controller 21 of the tugboat 2.

[0062] After calculating the planned propulsion vector 53 and the planned turning moment 54 of the subject ship 1, the controller 31 further calculates a target propulsion vector of the at least one thruster of the subject ship 1 and a target propulsion vector of the at least one tugboat 2 based on the following information: the environmental information, the subject ship position and azimuth information, and the tugboat position and azimuth information that have been obtained; ship maneuvering pattern information about the ship maneuvering pattern that has been set; the aforementioned subject ship thrust plan information; and the information contained in the database 34. In this manner, the planned propulsion vector 53 and the planned turning moment 54 of the subject ship 1 can be distributed between the at least one thruster of the subject ship 1 and the at least one tugboat 2 (each tugboat 2 is assumed to be one thruster).

[0063] For example, the controller 31 calculates the target propulsion vector of the at least

one thruster of the subject ship 1 and the target propulsion vector of the at least one tugboat 2, such that an evaluation function J shown below is minimized.

[0064] [Math. 1]

$$J := (r - u)^T W_1 (r - u) + \int_0^T u^T W_2 u \; dt + (V_0 - v)^T W_3 (v_0 - v) \quad \text{(Equation 1)},$$

where

r represents an added-up thrust command (the planned propulsion vector 53 and the planned turning moment 54 of the subject ship 1),

u represents a total thrust value of the thruster of the subject ship and the tugboat,

v_0 represents predetermined thrusts (in the fore-aft direction and port-starboard direction of the hull) and predetermined turning moments of the thruster of the subject ship and the tugboat (the number of elements is equal to the triple of the number of thrust generating sources),

v represents thrusts (in the fore-aft direction and port-starboard direction of the hull) and turning moments to be generated by the thruster of the subject ship and the tugboat (the number of elements is equal to the triple of the number of thrust generating sources),

W_1 and W_2 each represent a weighting matrix (3 × 3),

W_3 represents a weighting matrix (a square matrix; the number of elements is equal to the double of the number of thrust generating sources), and

T represents an evaluation time (several seconds to several hundreds of seconds).

[0065] The first term in the right-hand side of Equation 1 serves to reduce a difference between the added-up thrust command, which is the result of adding the external forces applied to the hull to a necessary thrust for maneuvering the subject ship, and an added-up value of the distributed thrusts. The second term in the right-hand side of Equation 1 is a weighted square sum of the added-up value of the distributed thrusts during a period from the start of the calculation (t = 0) until the elapse of a predetermined time T, and serves to reduce thrust generation. The third term in the right-hand side of Equation 1 serves to reduce differences of the distributed thrusts of the respective thrusters from predetermined values given in advance.

[0066] The controller 31 displays the calculated target propulsion vector of the at least one thruster of the subject ship 1 and the calculated target propulsion vector of the at least one tugboat 2 on the screen of the display 32.

[0067] The controller 31 further calculates a predicted position and a predicted azimuth of the subject ship 1 after the elapse of the predetermined time, and displays the aforementioned subject ship predicted profile line 55 on the screen of the display 32. For example, the controller 31 calculates the predicted position and the predicted azimuth of the subject ship 1

after the elapse of the predetermined time based on, for example, the hull model of the subject ship 1 (including the displacement, ship shape, etc.), the aforementioned subject ship thrust plan information and environmental information, and the underwater topography.

[0068] The controller 31 may transmit not only the subject ship thrust plan information, but also, for example, subject-ship-generating thrust information about the target propulsion vector of the at least one thruster of the subject ship 1 and tugboat-generating thrust information about the target propulsion vector of the at least one tugboat 2 to the controller 11 of the subject ship 1 via the communicator 33 and the communicator 13 of the subject ship 1. In this case, the screen of the display 12 of the subject ship 1 may be the same as the one shown in FIG. 2.

[0069] Similarly, the controller 31 may transmit not only the subject ship thrust plan information, but also, for example, the subject-ship-generating thrust information and the tugboat-generating thrust information to the controller 21 of the tugboat 2 via the communicator 33 and the communicator 23 of the tugboat 2. In this case, the screen of the display 22 installed in the at least one tugboat 2 may be the same as the one shown in FIG. 2.

[0070] As described above, in the ship maneuvering supporting system 4 of the present embodiment, not only the target propulsion vector of the tugboat 2, but also the target propulsion vector of the thruster of the subject ship 1 is displayed on the screen of the display 32. Therefore, a person who looks at the screen of the display 32 can take the thrust of the thruster of the subject ship 1 into consideration, and can clearly recognize the movement of the subject ship 1.

[0071] Moreover, in the present embodiment, the planned propulsion vector 53 and the planned turning moment 54 of the subject ship 1 are also displayed on the screen of the display 32, and thus the movement of the subject ship 1 with respect to the pivot point 51 is visualized. Therefore, the person who looks at the screen of the display 32 can recognize the movement of the subject ship 1 more clearly.

[0072] Furthermore, in the present embodiment, the subject ship predicted profile line 55 is also displayed on the screen of the display 32. Therefore, the person who looks at the screen of the display 32 can imagine changes that will occur in the position and the azimuth of the subject ship 1 until the elapse of the predetermined time.

[0073] <Variations>

In the above-described embodiment, the controller 31 of the terminal 3 displays not only the target propulsion vector of the at least one thruster of the subject ship 1 and the target propulsion vector of the at least one tugboat 2, but also the planned propulsion vector 53 and the planned turning moment 54 of the subject ship 1 and the subject ship predicted profile line 55 on

the screen of the display 32. However, as shown in FIG. 7, the displaying of the planned propulsion vector 53 and the planned turning moment 54 of the subject ship 1 and the subject ship predicted profile line 55 may be omitted.

[0074] Alternatively, as shown in FIG. 8, only the subject ship predicted profile line 55 may be displayed on the screen of the display 32, and the displaying of the target propulsion vector of the at least one thruster of the subject ship 1, the target propulsion vector of the at least one tugboat 2, and the planned propulsion vector 53 and the planned turning moment 54 of the subject ship 1 may be omitted. Also in this case, a person who looks at the screen of the display 32 can imagine changes that will occur in the position and the azimuth of the subject ship until the elapse of the predetermined time. Therefore, the person who looks at the screen of the display 32 can clearly recognize the movement of the subject ship 1.

[0075] The above-described variations are applicable also to Embodiment 2.

[0076] (Embodiment 2)

Next, a ship maneuvering supporting system according to Embodiment 2 of the present invention is described with reference to FIG. 9. In the present embodiment, the terminal 3 includes a controller 31' as shown in FIG. 9. The terminal 3 further includes: a first inputter 36, with which a user inputs the ship maneuvering pattern information described in Embodiment 1; and a second inputter 37, with which the user inputs the subject ship thrust plan information described in Embodiment 1.

[0077] For example, the first inputter 36 may be a touch panel or a keyboard. For example, as shown in FIG. 10, the second inputter 37 may include: a turning dial 37a to input the direction of the planned turning moment 54 (to specify whether it is left turning TL or right turning TR) and the magnitude of the planned turning moment 54; and a joystick 37b to input the direction and the magnitude of the planned propulsion vector 53. Regarding the joystick 37b, one side and the other side of the direction in which the turning dial 37a and the joystick 37b are arranged are a port direction L and a starboard direction R of the subject ship 1, respectively. One side of the direction orthogonal to the direction in which the turning dial 37a and the joystick 37b are arranged is a bow direction F of the subject ship 1.

[0078] The controller 31' of the present embodiment is different from the controller 31 of Embodiment 1 in the following points: the controller 31' does not set the ship maneuvering pattern and the optimum route, and does not calculate the planned propulsion vector 53 and the planned turning moment 54 of the subject ship 1.

[0079] Specifically, the controller 31' obtains the ship maneuvering pattern information that is inputted with the first inputter 36, and obtains the subject ship thrust plan information that is

inputted with the second inputter 37. The subject ship thrust plan information is information about the planned propulsion vector 53 and the planned turning moment 54 of the subject ship 1. Similar to Embodiment 1, the controller 31' calculates the target propulsion vector of the at least one thruster of the subject ship 1 and the target propulsion vector of the at least one tugboat 2 based on the environmental information, the subject ship position and azimuth information, the tugboat position and azimuth information, the ship maneuvering pattern information, the subject ship thrust plan information, and the information contained in the database 34.

[0080] Also in the present embodiment, the screen of the display 32 is the same as the one shown in FIG. 2. Specifically, similar to Embodiment 1, the controller 31' displays the pivot point 51 as well as the planned propulsion vector 53 and the planned turning moment 54 of the subject ship 1 on the screen of the display 32. The controller 31' further displays the target propulsion vector of the at least one thruster of the subject ship 1 and the target propulsion vector of the at least one tugboat 2 on the screen of the display 32. The controller 31' further displays the subject ship predicted profile line 55 on the screen of the display 32.

[0081] The present embodiment provides the same advantageous effects as those provided by Embodiment 1. Since the second inputter 37 is adopted in the present embodiment, the user can change the subject ship thrust plan information to be inputted, while checking the screen of the display 32.

[0082] (Other Embodiments)

The present invention is not limited to the above-described embodiments. Various modifications can be made without departing from the scope of the present invention.

[0083] For example, the subject ship 1 need not include the thruster. In this case, if the controller (31 or 31') of the terminal 3 displays at least the planned propulsion vector 53 and the planned turning moment 54 of the subject ship 1 on the screen of the display 32 as shown in FIG. 11, the movement of the subject ship 1 with respect to the pivot point 51 is visualized. Therefore, a person who looks at the screen of the display 32 can clearly recognize the movement of the subject ship 1.

[0084] In a case where the subject ship 1 includes no thruster, the subject ship 1 is assisted by a plurality of tugboats 2. In this case, the ship maneuvering pattern includes a manner of assisting the subject ship 1 by the plurality of tugboats 2. The controller (31 or 31') calculates the target propulsion vector of each of the tugboats based on the environmental information, the subject ship position and azimuth information, the tugboat position and azimuth information, the ship maneuvering pattern information, the subject ship thrust plan information, and the information contained in the database 34.

[0085] In the above case, as shown in FIG. 11, the controller (31 or 31') may display the target propulsion vectors of the respective tugboats 2 together with the planned propulsion vector 53 and the planned turning moment 54 of the subject ship 1 on the screen of the display 32. In the example shown in FIG. 11, each of target propulsion vectors 84 to 86 of three tugboats 2 is displayed as an arrow whose start point is a center point within the tugboat profile line 20. In the example shown in FIG. 11, the subject ship predicted profile line 55, which indicates a predicted position and a predicted azimuth of the subject ship 1 after the elapse of the predetermined time, is also displayed. Alternatively, as shown in FIG. 12, the displaying of the target propulsion vectors of the respective tugboats 2 and the subject ship predicted profile line 55 may be eliminated, and only the planned propulsion vector 53 and the planned turning moment 54 of the subject ship 1 may be displayed.

[0086] The target propulsion vectors of the respective tugboats 2 are results of resolving the planned propulsion vector 53 and the planned turning moment 54 of the subject ship 1. In other words, the planned propulsion vector 53 and the planned turning moment 54 of the subject ship 1 are results of synthesizing the target propulsion vectors of the respective tugboats 2.

[0087] As described in Embodiment 1, in a case where the controller 11 installed in the subject ship 1 or the controller 21 installed in one tugboat 2 sets the ship maneuvering pattern of the subject ship 1 and so forth, the controller (11 or 21) is configured in the same manner as the controller 31 shown in FIG. 3 or the controller 31' shown in FIG. 9. In this case, the ship maneuvering supporting system 4 need not include the terminal 3. However, in a case where the ship maneuvering supporting system 4 includes the terminal 3 as in Embodiment 1 or Embodiment 2, the conductor can conduct the maneuvering without being aboard the subject ship 1 or the tugboat 2, while looking at the screen of the display 32 of the terminal 3.

[0088] The subject ship 1 may be an unmanned ship. In this case, it is unnecessary to install the display 12 in the subject ship 1. The tugboat 2 may also be an unmanned tugboat. In this case, it is unnecessary to install the display 22 in the tugboat 2.

[0089] (Summary)

A ship maneuvering supporting system according to one aspect of the present invention is a ship maneuvering supporting system that is used in assisting a subject ship including at least one thruster by at least one tugboat, the ship maneuvering supporting system including: at least one display including a screen; and a controller that obtains subject ship position and azimuth information about a position and an azimuth of the subject ship and tugboat position and azimuth information about a position and an azimuth of the at least one tugboat, and displays a subject ship profile line and at least one tugboat profile line on the screen, the subject

ship profile line indicating the position and the azimuth of the subject ship, the at least one tugboat profile line indicating the position and the azimuth of the at least one tugboat. The controller calculates a target propulsion vector of the at least one thruster of the subject ship and a target propulsion vector of the at least one tugboat, and displays the target propulsion vector of the at least one thruster of the subject ship and the target propulsion vector of the at least one tugboat on the screen.

[0090] According to the above configuration, not only the target propulsion vector of the tugboat, but also the target propulsion vector of the thruster of the subject ship is displayed on the screen. Therefore, a person who looks at the screen of the display can take the thrust of the thruster of the subject ship into consideration, and can clearly recognize the movement of the subject ship.

[0091] The controller may calculate a planned propulsion vector of the subject ship and a planned turning moment of the subject ship, the planned propulsion vector being on a straight line passing through a pivot point of the subject ship, the planned turning moment being a moment about the pivot point, and may display the planned propulsion vector and the planned turning moment on the screen. The target propulsion vector of the at least one thruster of the subject ship and the target propulsion vector of the at least one tugboat may be results of resolving the planned propulsion vector and the planned turning moment. According to this configuration, the movement of the subject ship with respect to the pivot point is visualized. Therefore, a person who looks at the screen of the display can recognize the movement of the subject ship more clearly.

[0092] The controller may calculate a predicted position and a predicted azimuth of the subject ship after an elapse of a predetermined time, and may display a subject ship predicted profile line indicating the predicted position and the predicted azimuth on the screen. According to this configuration, a person who looks at the screen of the display can imagine changes that will occur in the position and the azimuth of the subject ship until the elapse of the predetermined time.

[0093] For example, the controller may include a database containing subject ship information about specifications of the subject ship and tugboat information about specifications of the at least one tugboat, and may calculate the target propulsion vector of the at least one thruster of the subject ship and the target propulsion vector of the at least one tugboat based on the following information: environmental information including weather information and/or oceanographic phenomenon information; the subject ship position and azimuth information; the tugboat position and azimuth information; subject ship thrust plan information about a planned

propulsion vector of the subject ship and a planned turning moment of the subject ship, the planned propulsion vector being on a straight line passing through a pivot point of the subject ship, the planned turning moment being a moment about the pivot point; ship maneuvering pattern information about a ship maneuvering pattern that includes a manner of using the at least one thruster of the subject ship and a manner of assisting the subject ship by the at least one tugboat; and information contained in the database.

[0094] A ship maneuvering supporting system according to another aspect of the present invention is a ship maneuvering supporting system that is used in assisting a subject ship by at least one tugboat, the ship maneuvering supporting system including: at least one display including a screen; and a controller that obtains subject ship position and azimuth information about a position and an azimuth of the subject ship and tugboat position and azimuth information about a position and an azimuth of the at least one tugboat, and displays a subject ship profile line and at least one tugboat profile line on the screen, the subject ship profile line indicating the position and the azimuth of the subject ship, the at least one tugboat profile line indicating the position and the azimuth of the at least one tugboat. The controller calculates a predicted position and a predicted azimuth of the subject ship after an elapse of a predetermined time, and displays a subject ship predicted profile line indicating the predicted position and the predicted azimuth on the screen.

[0095] According to the above configuration, a person who looks at the screen can imagine changes that will occur in the position and the azimuth of the subject ship until the elapse of the predetermined time. Therefore, the person who looks at the screen can clearly recognize the movement of the subject ship.

[0096] For example, the at least one display may include a terminal display included in a terminal that is independent of the subject ship and the at least one tugboat. The at least one display may include one of, or both, a subject ship display installed in the subject ship and at least one tugboat display installed in the at least one tugboat.

[0097] A ship maneuvering supporting system according to yet another aspect of the present invention is a ship maneuvering supporting system that is used in assisting a subject ship by tugboats, the ship maneuvering supporting system including: at least one display including a screen; and a controller that obtains subject ship position and azimuth information about a position and an azimuth of the subject ship and tugboat position and azimuth information about positions and azimuths of the respective tugboats, and displays a subject ship profile line and tugboat profile lines on the screen, the subject ship profile line indicating the position and the azimuth of the subject ship, the tugboat profile lines indicating the positions and the azimuths of

the respective tugboats. The controller calculates a planned propulsion vector of the subject ship and a planned turning moment of the subject ship, the planned propulsion vector being on a straight line passing through a pivot point of the subject ship, the planned turning moment being a moment about the pivot point, and displays the planned propulsion vector and the planned turning moment on the screen.

[0098] According to the above configuration, the movement of the subject ship with respect to the pivot point is visualized. Therefore, a person who looks at the screen of the display can clearly recognize the movement of the subject ship.

[0099] For example, the controller may calculate a target propulsion vector of each of the tugboats, and may display the target propulsion vectors of the respective tugboats on the screen, and the target propulsion vectors of the respective tugboats may be results of resolving the planned propulsion vector and the planned turning moment of the subject ship.

[0100] The controller may calculate a predicted position and a predicted azimuth of the subject ship after an elapse of a predetermined time, and may display a subject ship predicted profile line indicating the predicted position and the predicted azimuth on the screen. According to this configuration, a person who looks at the screen of the display can imagine changes that will occur in the position and the azimuth of the subject ship until the elapse of the predetermined time.

[0101] For example, the controller may include a database containing subject ship information about specifications of the subject ship and tugboat information about specifications of the tugboats, and may calculate target propulsion vectors of the respective tugboats based on the following information: environmental information including weather information and/or oceanographic phenomenon information; the subject ship position and azimuth information; the tugboat position and azimuth information; subject ship thrust plan information about the planned propulsion vector of the subject ship and the planned turning moment of the subject ship, the planned propulsion vector being on the straight line passing through the pivot point of the subject ship, the planned turning moment being a moment about the pivot point; ship maneuvering pattern information about a ship maneuvering pattern that includes a manner of assisting the subject ship by the tugboats; and information contained in the database.

[0102] For example, the at least one display may include a terminal display included in a terminal that is independent of the subject ship and the tugboats. The at least one display may include tugboat displays installed in the respective tugboats.

[0103] The above ship maneuvering supporting system may further include an inputter with which a user inputs the subject ship thrust plan information. According to this configuration,

the user can change the subject ship thrust plan information to be inputted, while checking the screen of the display.

Reference Signs List

[0104]

1 subject ship
10 subject ship profile line
12 display (subject ship display)
2 tugboat
20 tugboat profile line
22 display (tugboat display)
31 controller
32 display (terminal display)
34 database
4 ship maneuvering supporting system
51 pivot point
53 planned propulsion vector
54 planned turning moment
55 subject ship predicted profile line
71, 72, 81 to 83 target propulsion vector

CLAIMS

1. A ship maneuvering supporting system that is used in assisting a subject ship including at least one thruster by at least one tugboat, the ship maneuvering supporting system comprising:

at least one display including a screen; and

a controller that obtains subject ship position and azimuth information about a position and an azimuth of the subject ship and tugboat position and azimuth information about a position and an azimuth of the at least one tugboat, and displays a subject ship profile line and at least one tugboat profile line on the screen, the subject ship profile line indicating the position and the azimuth of the subject ship, the at least one tugboat profile line indicating the position and the azimuth of the at least one tugboat, wherein

the controller calculates a target propulsion vector of the at least one thruster of the subject ship and a target propulsion vector of the at least one tugboat, and displays the target propulsion vector of the at least one thruster of the subject ship and the target propulsion vector of the at least one tugboat on the screen.

2. The ship maneuvering supporting system according to claim 1, wherein

the controller calculates a planned propulsion vector of the subject ship and a planned turning moment of the subject ship, the planned propulsion vector being on a straight line passing through a pivot point of the subject ship, the planned turning moment being a moment about the pivot point, and displays the planned propulsion vector and the planned turning moment on the screen, and

the target propulsion vector of the at least one thruster of the subject ship and the target propulsion vector of the at least one tugboat are results of resolving the planned propulsion vector and the planned turning moment.

3. The ship maneuvering supporting system according to claim 1 or 2, wherein

the controller calculates a predicted position and a predicted azimuth of the subject ship after an elapse of a predetermined time, and displays a subject ship predicted profile line indicating the predicted position and the predicted azimuth on the screen.

4. The ship maneuvering supporting system according to any one of claims 1 to 3, wherein

the controller includes a database containing subject ship information about

specifications of the subject ship and tugboat information about specifications of the at least one tugboat, and calculates the target propulsion vector of the at least one thruster of the subject ship and the target propulsion vector of the at least one tugboat based on the following information:

environmental information including weather information and/or oceanographic phenomenon information;

the subject ship position and azimuth information;

the tugboat position and azimuth information;

subject ship thrust plan information about a planned propulsion vector of the subject ship and a planned turning moment of the subject ship, the planned propulsion vector being on a straight line passing through a pivot point of the subject ship, the planned turning moment being a moment about the pivot point;

ship maneuvering pattern information about a ship maneuvering pattern that includes a manner of using the at least one thruster of the subject ship and a manner of assisting the subject ship by the at least one tugboat; and

information contained in the database.

5. A ship maneuvering supporting system that is used in assisting a subject ship by at least one tugboat, the ship maneuvering supporting system comprising:

at least one display including a screen; and

a controller that obtains subject ship position and azimuth information about a position and an azimuth of the subject ship and tugboat position and azimuth information about a position and an azimuth of the at least one tugboat, and displays a subject ship profile line and at least one tugboat profile line on the screen, the subject ship profile line indicating the position and the azimuth of the subject ship, the at least one tugboat profile line indicating the position and the azimuth of the at least one tugboat, wherein

the controller calculates a predicted position and a predicted azimuth of the subject ship after an elapse of a predetermined time, and displays a subject ship predicted profile line indicating the predicted position and the predicted azimuth on the screen.

6. The ship maneuvering supporting system according to any one of claims 1 to 5, wherein

the at least one display includes a terminal display included in a terminal that is independent of the subject ship and the at least one tugboat.

7. The ship maneuvering supporting system according to any one of claims 1 to 6, wherein

the at least one display includes one of, or both, a subject ship display installed in the subject ship and at least one tugboat display installed in the at least one tugboat.

8. A ship maneuvering supporting system that is used in assisting a subject ship by tugboats, the ship maneuvering supporting system comprising:

at least one display including a screen; and

a controller that obtains subject ship position and azimuth information about a position and an azimuth of the subject ship and tugboat position and azimuth information about positions and azimuths of the respective tugboats, and displays a subject ship profile line and tugboat profile lines on the screen, the subject ship profile line indicating the position and the azimuth of the subject ship, the tugboat profile lines indicating the positions and the azimuths of the respective tugboats, wherein

the controller calculates a planned propulsion vector of the subject ship and a planned turning moment of the subject ship, the planned propulsion vector being on a straight line passing through a pivot point of the subject ship, the planned turning moment being a moment about the pivot point, and displays the planned propulsion vector and the planned turning moment on the screen.

9. The ship maneuvering supporting system according to claim 8, wherein

the controller calculates a target propulsion vector of each of the tugboats, and displays the target propulsion vectors of the respective tugboats on the screen, and

the target propulsion vectors of the respective tugboats are results of resolving the planned propulsion vector and the planned turning moment of the subject ship.

10. The ship maneuvering supporting system according to claim 8 or 9, wherein

the controller calculates a predicted position and a predicted azimuth of the subject ship after an elapse of a predetermined time, and displays a subject ship predicted profile line indicating the predicted position and the predicted azimuth on the screen.

11. The ship maneuvering supporting system according to any one of claims 8 to 10, wherein

the controller includes a database containing subject ship information about

specifications of the subject ship and tugboat information about specifications of the tugboats, and calculates target propulsion vectors of the respective tugboats based on the following information:

environmental information including weather information and/or oceanographic phenomenon information;

the subject ship position and azimuth information;

the tugboat position and azimuth information;

subject ship thrust plan information about the planned propulsion vector of the subject ship and the planned turning moment of the subject ship, the planned propulsion vector being on the straight line passing through the pivot point of the subject ship, the planned turning moment being a moment about the pivot point;

ship maneuvering pattern information about a ship maneuvering pattern that includes a manner of assisting the subject ship by the tugboats; and

information contained in the database.

12. The ship maneuvering supporting system according to any one of claims 8 to 11, wherein

the at least one display includes a terminal display included in a terminal that is independent of the subject ship and the tugboats.

13. The ship maneuvering supporting system according to any one of claims 8 to 12, wherein

the at least one display includes tugboat displays installed in the respective tugboats.

14. The ship maneuvering supporting system according to claim 4 or 11, further comprising an inputter with which a user inputs the subject ship thrust plan information.