It is an object of the invention to provide system that overcomes or at least reduces the problems indicated above.

The foregoing and other objects are achieved by the features of the independent claims. Further implementation forms are apparent from the dependent claims, the description and the figures.

According to a first aspect, there is provided a tugboat for assisting a marine vessel to maneuver, the tugboat comprising:

- an engine to drive one or more propulsors, the one or more propulsors having a controllable direction of thrust,
- a towing line for establishing a pulling connection between the marine vessel and the tugboat,
- a first sensor arrangement configured for sensing a size and direction of a pulling force that the towing line exerts on the tugboat,
- a second sensor arrangement configured for sensing an orientation of the tugboat,
- a controller configured to receive a signal from the first sensor arrangement and a signal from the second sensor arrangement,
- the controller being informed of a size and direction of thrust generated by the one or more propulsors,
- the controller being configured to determine if a first safety threshold, associated with said tugboat, is exceeded on the basis of:
    - the sensed size and direction of thrust generated by said one or more propulsors,
    - the sensed size and direction of the pulling force, and
    - the sensed orientation of the tugboat.

By providing a tugboat with a controller informed of the forces acting on the tugboat and of the orientation of the tugboat it becomes possible to create an automatic system of preventing capsizing and/or sinking of the tugboat due to e.g. excessive force on the towing line.

In a first possible implementation form of the first aspect,

the controller is configured to reduce the size, and/or change the direction, of the thrust generated by the one or more propulsors when the controller has determined that the tugboat has exceeded the first safety threshold.

In a second possible implementation form of the first aspect,
the tugboat is provided with an arrangement for disconnecting the tugboat from the towing line in response to a command from the controller.

In a third possible implementation form of the first aspect, the arrangement comprises a device for severing the towing line.

In a fourth possible implementation form of the first aspect,
the controller is configured to cause severing of the towing line when the controller has determined that the tugboat has exceeded a second safety threshold that is higher than said first safety threshold.

In a fifth possible implementation form of the first aspect,
the first and second safety thresholds correspond to a risk of the tugboat capsizing and/or wherein the first and second safety thresholds correspond to a risk of the tugboat sinking.

In a sixth possible implementation form of the first aspect,
the controller is configured to determine that the tugboat is at the risk of capsizing or sinking on the basis of a computer model that simulates the behavior of the tugboat.

In a seventh possible implementation form of the first aspect,
the controller is provided with a mathematical model of said tugboat.

According to a second aspect, there is provided a method of operating a tugboat, the method comprising:
determining a size and direction of a thrust created by one or more propulsors of the tugboat;

determining a size and direction of a pulling force applied to the tugboat by a towing line;
determining an orientation of the tugboat; and

determining if a combination of the size and direction of the thrust, the size and direction of the pulling force, and the orientation of the tugboat exceeds a safety threshold associated with said tugboat.

In a first possible implementation form of the second aspect the method further comprises adjusting the size and/or direction of the thrust in order to prevent the tugboat from exceeding a safety threshold.

In a second possible implementation form of the second aspect, the method further comprises severing the towing line when a safety threshold is exceeded.

These and other aspects of the invention will be apparent from and the embodiment(s) described below.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following detailed portion of the present disclosure, the invention will be explained in more detail with reference to the example embodiments shown in the drawings, in which:

Fig. 1 is a side view of an assisted vessel and a plurality of tugboats during an assist operation,

Fig. 2 is a top view of the assisted vessel and plurality of tugboats of Fig. 1 during an assist operation with one additional tugboat on the side of the assisted vessel,

Fig. 3 is a top view of the assisted vessel and a plurality of tugboats of Fig. 1 during an assist operation with two additional tugboats on the side of the assisted vessel,

Fig. 4 is a system diagram of a system with a remote control unit for a pilot, a remote control unit for a control center and a control unit for each tugboat in the system,

Fig. 5 is a side view of a tugboat with a crane arm in a rest position,

Fig. 6 is a side view of the tugboat of Fig. 5 in a lifted position holding a towing line,

Fig. 7 is a top view of the tugboat of Fig. 5 with the crane in a rest position,

navigation module includes nautical charts required for safe navigation of the tugboat 2 and forms a navigation system for the tugboat 2. The navigational module allows the electronic control unit 50 to navigate the tugboat 2 from berth to a target position, e.g. a mobilization position, i.e. a position where the tugboat 2 is to be deployed for assisting a marine vessel 1 to maneuver. The navigation module also allows the electronic control unit to navigate the tugboat back to berth from mobilized position. Thus, upon receiving instruction via the wireless communication unit 54 the electronic control unit 50 sails the tugboat 2 autonomously from berth to a mobilization position and vice versa. Collision with obstacles in the way path of the tugboat 2 is avoided by the electronic control unit deploying the collision avoidance module that is explained in greater detail further below. With the assistance of the collision avoidance unit the electronic control unit 50 takes evasive action if needed in order to avoid a collision with an object, such as another marine vessel, land, a bridge pillar or shallow waters.

The navigation system is preferably an autonomous navigation system configured to maneuver the tugboat 2 to in all scenarios within the intentions of COLREG (Convention on the International Regulations for Preventing Collisions at Sea, 1972). COLREG compliant algorithms are be stored in the electronic control unit 50 so that electronic control unit 50 can make the necessary course corrections in order to safely navigate in all scenarios.

The collision avoidance module comprises regulatory information on preventing collisions, such as e.g. COLREGs, and takes evasive action in accordance with the rules. The collision avoidance module enables the electronic control unit 2 to determine when and which evasive action to take.

The electronic control unit 50 is also provided with an image recognition module allowing the electronic control unit 50 to recognize an image indicating a strong point on the side of the hull 3 and assisted marine vessel 1. In an embodiment the electronic control unit is with

electronic control unit can further be configured to sever the towline 10 when a safety threshold is exceeded.

In an embodiment the boat or ship (which could be any type of boat, ship or vessel and does not need to be a tugboat 2) is provided with a collision prevention system that can assist the crew to avoid collision with obstacles such as e.g. other boats or ships. In an embodiment the boat or ship is configured to issue a warning to the crew if a first risk level is exceeded, and in an embodiment the boat or ship is also configured to take evasive action if the crew does take evasive action when a second risk level that is higher than the first risk level is exceeded. The collision prevention system can also be used for an autonomously operating boat or ship, in which case the collision prevention system issues an alarm that is transmitted wirelessly to a remote recipient when a first risk level is exceeded, and the navigation prevention system takes evasive action when the second risk level is exceeded. Fig. 33 shows a scenario on a chart for illustrating the functioning of the collision prevention system.

As shown in Fig. 33, the collision prevention system (can be integral part of the electronic control unit 50) has assigned a first collision zone 180 around the boat 2 and has assigned a second collision zone 81 around the boat 2, the second collision zone 81 surrounding the first collision zone 180. The shape and size of the first collision zone 180 and the shape and size of the second collision zone 81 depend on the speed and heading of the boat or ship 2. The speed and heading of the boat or ship 2 are illustrated by vector 82.

The first collision zone 180 and the second collision zone 81 are larger in the direction of the heading of the boat or ship and will become larger at least in the direction of the heading with increasing speed of the boat or ship 2 and preferably also slightly larger in the direction traverse to the heading.

As shown in Fig. 33, the collision prevention system has detected several obstacles using the sensors on the boats 2, such as e.g. the RADAR, LIDAR and camera. In this example the detected obstacles include a pleasure boat (yacht) 85, a fishing boat 87, a cargo ship 86

and an island 88. However, it is understood that these are merely examples of possible types of obstacles, and other types of obstacles can also be detected.

The collision prevention system is configured to assign a category to each detected obstacle. Examples of categories are e.g. watercraft, fixed structures, shallow water, land and categories preferably including a plurality of categories of watercraft, including boats, ships, and said plurality of categories of boats yet even more preferably including fishing boats, tugboats, speedboats, yachts and sailing yachts and said categories of ships comprising cargo vessels, navy vessels, cruise ships and ferries. However, it is understood that this list merely provides examples and this list is not exhaustive.

Each category has associated information on e.g. the likeliness of the detected obstacle to change position, change course and/or change speed, preferably in relation to the navigation plan of the detected obstacle (if available) and using a mathematical model of the detected obstacle (if available). Each category may also have associated thereto information on the shape and size of the first collision zone and the second collision zone, preferably in relation to the detected speed and heading (if any) of the detected obstacle.

In an embodiment the navigation system is configured to track the course of a detected obstacle. In an embodiment the navigation system is configured to determine the likeliness of a detected obstacle to change course and/or speed, preferably on the basis of the category in which the obstacle has been placed.

Based on the determined category and on the speed of the detected obstacle, the navigation system determines a collision zone 83 around each detected obstacle

In the example of Fig. 33 the boat 2 has a planned route 178. Following this route 178 the navigation system will detect after a while that the collision zone 83 of the pleasure boat 85 overlaps with the second collision zone 82 of the boat. Thereupon, the collision avoidance system transmits a warning wirelessly to the remote control center 200 and/or the remote control unit 150. Unless the boat 2 receives wireless instructions from the

remote control center 200 and/or from the remote control unit 150, it will continue the planned course 178. Assuming that no such wireless instruction to change route is received, the collision avoidance system will after a while detect that the collision zone 83 of the pleasure boat 85 overlaps with the first collision zone 180 of the boat 2 and thereupon the collision avoidance system takes evasive action, preferably in accordance with COLREGs, by following a new route 179 that ensures that the boat 2 passes behind the pleasure boat 85 at a safe distance. For determining evasive action the collision avoidance system takes into account the navigational limitations of the boat or ship 2, preferably using a mathematical model (if available) of the boat or ship 2.

Simultaneously, the collision avoidance system broadcasts its change in route, preferably using VHF communication such as standardized Marine VHF communication (e.g. channel 16, which is used for urgent safety messages) and preferably in accordance with international standards, such as e.g. "IMO Standard Marine Navigational Vocabulary". In the event where both vessels have the same collision avoidance system, a standardized communication protocol will be used for the data exchange.

In an embodiment the portable control unit 150 can be used to enhance the traditional VHF communication from the assisted vessel to a conventional tugboat. The system is configured so that the pilot can issue a command to control the whole system, including the tugboats 2 and the assisted marine vessel 1 in dynamic positioning mode. The interface on the formal control unit 150 can include additional sensors to support the DP operation and enhance the position data available to the captain (of the assisted marine vessel 1) and pilot.

In an embodiment the tugboat 2 is provided with an automatic anchoring system (not shown). The automatic anchoring system can be provided a safety feature and the electronic control unit 50 can in an embodiment be configured to trigger the automatic anchoring system as a safe fall back, e.g. the failure mode supports this action.

CLAIMS

1. A tugboat for assisting a marine vessel to maneuver, said tugboat comprising:

- an engine to drive one or more propulsors, the one or more propulsors having a controllable direction of thrust,

- a towing line for establishing a pulling connection between the marine vessel and the tugboat,

- a first sensor arrangement configured for sensing a size and direction of a pulling force that the towing line exerts on the tugboat,

- a second sensor arrangement configured for sensing an orientation of the tugboat,

- a controller configured to receive a signal from said first sensor arrangement and a signal from said second sensor arrangement,

- said controller being informed of a size and direction of thrust generated by said one or more propulsors,

- said controller being configured to determine if a first safety threshold, associated with said tugboat, is exceeded on the basis of:

    - the sensed size and direction of thrust generated by said one or more propulsors,

    - the sensed size and direction of the pulling force, and

    - the sensed orientation of the tugboat.

2. A tugboat according to claim 1, wherein said controller is configured to reduce the size, and/or change the direction, of the thrust generated by the one or more propulsors when the controller has determined that the tugboat has exceeded said first safety threshold.

3. A tugboat according to claim 1 or 2, wherein said tugboat is provided with an arrangement for disconnecting the tugboat from said towing line in response to a command from said controller.

4. A tugboat according to claim 3, wherein said arrangement comprises a device for severing said towing line.

5. A tugboat according to claim 3 or 4, wherein said controller is configured to cause severing of said towing line when the controller has determined that the tugboat has exceeded a second safety threshold that is higher than said first safety threshold.

6. A tugboat according to any one of claims 1 to 5, wherein said first and second safety thresholds correspond to a risk of said tugboat capsizing and/or wherein said first and second safety thresholds correspond to a risk of said tugboat sinking.

7. A tugboat according to any one of claims 1 to 6, wherein said controller is configured to determine that said tugboat is at the risk of capsizing or sinking on the basis of a computer model that simulates the behavior of said tugboat.

8. A tugboat according to any one of claims 1 to 7, wherein said controller is provided with a mathematical model of said tugboat.

9. A method of operating a tugboat, said method comprising

determining a size and direction of a thrust created by one or more propulsors of said tugboat;

determining a size and direction of a pulling force applied to said tugboat by a towing line;

determining an orientation of said tugboat; and

determining if a combination of the size and direction of the thrust, the size and direction of the pulling force, and the orientation of said tugboat exceeds a safety threshold associated with said tugboat.

10. A method according to claim 9, further comprising adjusting the size and/or direction of said thrust in order to prevent said tugboat from exceeding a safety threshold.

11. A method according to claim 9 or 10, further comprising severing the towing line when a safety threshold is exceeded.