

GUIDANCE OF MARINE VESSELS

FIELD OF THE INVENTION

5 The present invention relates to guidance of marine vessels. More specifically, the invention relates to guidance of unmanned marine vessels.

BACKGROUND OF THE INVENTION

 An unmanned marine vessel was described in PCT/IL2005/001329
10 from the same applicant. Such a marine vessel can carry a variety of payloads. Such payloads may be related to any task that the vessel is to fulfill, civil, military, reconnaissance, guard tasks, or any combination thereof. Payload on board vessels may include subsystems that relate to positioning of the vessel in relation to either a geographic grid or to a local object.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a flow chart describing an exemplary sequence of steps implemented by a vessel which follows a target boat and instructed to keep a specific distance from the target;

Fig. 2 is a flow chart describing an exemplary sequence of steps implemented by a vessel instructed to follow a specific course guided by a subsystem of the payload;

Fig. 3 is a block diagram describing the data flow from payload to vessel's guidance control system;

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DETAILED DESCRIPTION OF THE PRESENT INVENTION

The invention is typically implemented in an unmanned marine vessel, but the invention may also be implemented in a manned vessel. Such a vessel, as discussed above, can carry a variety of payloads, some of which or some subsystems of which can be used to aid in the guidance of the vessel. The payload utilizable in accordance with the present invention is any appliance useful in providing locational data, i.e. data bearing distance information to a target relative to an accepted geographical grid or to a local grid. In the art, optical and electromagnetic equipment are used to such ends. To better explain the invention, some examples are given in the following.

The control over the payload and vessel may be categorized in any of the three following possible categories. The first type relates to a vessel fully controlled by a remote control unit such that the control signals are initiated in the control unit and the response parameters are fed back to the same unit. The second type relates to an autonomous vessel fully responsible for initiating changes in sail parameters as required by the changing circumstances. The third type relates to a vessel having partial control over the cruise guidance, for example, at certain parts of the mission the control is fully managed by the control unit whereas at other occasions the mission is fully controlled by the vessel. The autonomy is in such case directed by an algorithm stored on board the vessel or somewhere else. Typically, however it is likely that a combined control is practiced, meaning a supervised autonomy keeping some control over the vessel.

Example 1, guidance to a target

A vessel carrying an electromagnetic radiation detection system uses
5 the payload for guidance purposes. Systems for locating and geolocating
radiation sources are known in the art, such as the system disclosed in US
Patent 5,719,584. Geolocating a radiating source may require several receiving
stations, which may require cooperation of more vessels or a vessel and a
stationary station, or a combination of such stations. If only the direction of the
10 radiating station is of consequence, the payload on board the vessel may be a
sufficient source of information for the boat maintaining a predetermined
direction relative to a target. Such payload typically detects either optical or RF
signals originating in the target or reflected by it. If, however the direction as
well as the distance to the target are required for fulfilling a mission, the payload
15 on board the vessel may not be sufficient, in such cases there may be need for
an additional data source, for example from an on shore station and/or from a
subsystem of the vessel itself. The use of a payload for electromagnetic
radiation detection can be efficiently exploited if the unmanned vessel is to
follow a specific radiation source. In such case, geolocating the source can be
20 considered of secondary importance, since the main mission is to follow and
approach the radiation source. For example, an optical detecting payload on
board the vessel is aimed at the target. From this point on, the boat is to
continue following a course functionally dependant upon the location of the

target as viewed by the payload of the vessel with reference to an inertial direction. The guiding function may be a zero order function (i.e. a constant angle) or a higher order function. The vessel maneuvers itself both as regards velocity and direction such that the projected courses converge both with
5 reference to the distance to be traveled and with respect to the time scale.

Example 2, guidance associated with velocity control

A vessel bearing a target acquisition system such as radar uses the acquisition system to guide the vessel. The vessel is instructed by wireless
10 communication to follow a target at a specific range. The event flow representing a velocity control of the vessel is described in **Fig. 1** to which reference is now made. In step **20** the vessel receives an operational instruction to stay at a specific distance D from a target. At step **22** the acquisition payload on board the vessel acquires the target, and at step **24** the distance to the
15 target is measured by payload. At decision step **26** if the distance measured is smaller than the required D, velocity is decreased at step **28**. If the distance is not smaller than D, velocity is increased in step **30**. In a next decision, at step **32**, the vessel verifies whether an operational instruction is in force. If it is still in force, the distance is measured and so on. Measuring of distance to the target
20 is accomplished using the range finder of the payload on board the vessel, either in a supervised manner or automatically.

Example 3, guidance associated with course control

A vessel carrying an electro-optic acquisition system uses the payload for guidance purposes. The output signal of a bearing finder, such as a resolver implemented in the payload is used to guide the vessel. To explain this, example reference is made to **Fig. 2**. The vessel receives instruction as to the course it should follow in step **60**. The vessel is to change to course D if it is not currently sailing in that direction. In step **62** the payload orients itself relative to the target. In decision step **66** the relative measured bearing to the target is compared to the one received in the instruction. If the measured relative bearing is not smaller than the required D, then the vessel is steered left in step **70**. If the measured relative bearing is smaller than D, the vessel is to steer right in step **70**. Subsequently, the vessel verifies whether an operational instruction is in force in step **74**, to resume course update if required.

Target acquisition systems require relating the acquisition payload to the target such that a direction to the target, (e.g. a boat) from the payload is established. This may also be referred to as a line of sight. The payload on a vessel implementing the invention is therefore expected to establish a direction (line of sight) to a target, once the target is acquired. For a guidance system in accordance with the invention it is convenient to relate to direction as issued by the acquisition system. This may be interpreted in using the line of sight as an axis of reference. This is implemented geometrically by generating a local circular coordinate system, also known as polar coordinate system, with respect to which the vessel is oriented. In such a grid the direction is referred to as an angle from the reference axis (relative to the vessel), in this case line of sight to

the target. Thus, a target bearing 0 means cruising in the direction towards the target, and any other degree would mean a deviation from that direction. A changeable course, whether related to a reference axis directed to a target or to a global bearing, would mean referring the vessel to different angles of the deviation from any reference axis. Either an automatic algorithm or a manual input can be used for managing such a course. Typically, the vessel can cruise in a constant course deviating from the direction to the target at a specific angle, etc.

Example 4, guidance associated with combined course and distance control

A vessel is required to change both course and velocity with respect to a target in its maneuvers in the water. Such changes may be implemented in the water by applying control over both the drive and steering systems. In **Fig. 3** to which reference is now made, a schematic block diagram is shown describing the data flow between subunits in a vessel implementing the invention. Signals **86** from the payload subsystem which contain locational data are fed into navigation processor **88** of the vessel. In the vessel, task manager **90**, a program that calculates the course and velocity modifications, is to be implemented by vessel cruise control **92** in order to achieve a desired maneuver with respect to the target. The instructions are interpreted by a vessel cruise control into mechanical parameters of the appropriate vessel's mechanical subunits.

Such mechanical subunits are typically the rudder (course modification) and the engine (velocity modification), together performing the necessary maneuvers to acquire a specific course in the water, either momentarily or continuously. In jet propelled vessels, the course control and maneuvering are performed by jet steering. Some vessels, typically small ones, employ a steerable external engine, which can be manipulated for both changing velocity and changing bearing.

CLAIMS

1. A system for controlling the cruise of a vessel comprising:
 - 5 • a subsystem of a payload of said vessel functional in generating locational data relating to a target;
 - a controller for controlling the cruise control units determining bearing and velocity of said vessel.
- 10 2. A payload for controlling the cruise of a vessel as in claim 1 further comprising an interpreting system of said vessel for accepting signals of said payload of said vessel and for moderating them to be accepted by said controller.
- 15 3. A system for controlling the cruise of a vessel as in claim 1 wherein said vessel is an unmanned vessel.
4. A system for controlling the cruise of a vessel as in claim 1 wherein said cruise control units selected from a group
20 consisting of a rudder and an engine, and any combination thereof.

5. A system for controlling the cruise of a vessel as in claim 1
5 wherein said cruise control units are selected from a group
consisting of a jet steering subunit, an engine and an external
steerable engine, or any combination thereof.

6. A method for guiding a vessel comprising:

- 10 • using a subsystem of a payload of said vessel for
obtaining locational data;
- determining at least a course of said vessel in relation to
said locational data.

15 7. A method for guiding a vessel as in claim 6 wherein said vessel
is guided relative to a reference axis of a polar coordinate
system, wherein said reference axis is a line of sight to a target.

8. A method for guiding a vessel as in claim 6 wherein said vessel
20 is guided relative to a distance from a target.

9. A method for guiding a vessel as in claim 6 wherein said vessel
is autonomous.

10. A method for guiding a vessel as in claim 6 wherein said vessel is fully remote controlled.

5 11. A method for guiding an autonomous vessel with respect to a target vessel, wherein said autonomous vessel keeps a functionally dependent course related to the location of said target vessel with a constant inertial reference.

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12. A method as in claim 11 for guiding an autonomous vessel with respect to a target vessel, wherein said autonomous vessel manoeuvres itself to keep said course, functionally dependent
15 upon the location of said target.

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