Remote radar image and radar tracking method for controlling unmanned Platforms

DESCRIPTION

FIELD

The invention relates to remote command and control solution involving unmanned vessels and remote radar data dissemination, and radar target tracking.

BACKGROUND OF THE INVENTION

1. Conventionally in all manned vessels or vehicles, which have radar installed on-board, radar spoke data processing and contact tracking are normally provided by a dedicated radar computer (hereinafter referred to as '*radar computer*'). For every angular sweep of the radar antenna, spoke data are collected and based on a dedicated algorithm, the strength of each contact echo is analysed and reported immediately to its dedicated display. The contact echoes will stay visible for a period of one complete sweep of the radar antenna, before being refreshed again by the next angular sweep of the radar antenna. The dedicated radar display provides a brief one-complete-sweep-of-the-radar-antenna image of the contact echoes around the vessel.

2. Each of these contact echoes are then analysed by the *radar computer* as they arrives, and compared against a list of contact echoes in their previous sweeps of the radar antenna. Contact track information is formed.

3. In some preferred conventional forms, once the radar data and images have been processed by the *radar computer*, radar contact tracks, with or without its images, could then be served via specialised dedicated ship-board networks, such as, but not limited to, NMEA2000.

4. In such a ship-board networked environment, it is not unusual that radar data and images are first processed by a thin-client on-board the *radar computer* and due to the voluminous data generated at the radar antenna, only contact track information are shared to the centralised server, which is then distributed to the other computers for display and possibly merging with the other contact track information derived from other sensors, such as, but not limited to, electronic chart information, automatic identification system (AIS), visible contacts from the day cameras, optical contacts from electro-optical (EO) cameras, and manual contacts introduced by watch personnel.

5. This contact track information is important and critical to the vessel-in-operation, where, timely and important decisions have to be made on surveillance, navigation, obstacle avoidance and record, whether by employing manual method, automatic method or both.

6. Regardless of the degree of autonomous capability of the *USV,* in performing its mission automatically and independently, the base operator still needs to have unambiguous appreciation of the sea situation. The intervention of the base operator to intercept and intervene in the running of the *USV* cannot be excluded. These situations normally arise and develop rather quickly. If the base operator does not have full information from the *USV's* radar images and contact information, it is almost impossible for the base operator to intervene correctly and timely.

7. To move from a manned vessel concept to a modern unmanned one therefore requires these radar data and/or images and contact track information to be transmitted timely over the air to its base operator.

8. There are 2 current issues here:

   a. The typical radar's 24-48 sweeps or any other sweep per minute of raw spoke data, averaging 2.4 – 1.2 seconds per scan, cannot be transmitted over the air in a timely manner and demands a high bandwidth over the air that can meaningfully be deployed.

   b. The base operator, in order to intervene in many of the out-of-the-normal situations, requires the *radar computer* to transmit some form of radar sweep data and/or image and contact track information to the base and/or on-board computers in a timely and regular manner, so that the base operator at the base and/or boat computers is able to correlate its detected radar echoes against the existing contact track information in order to have full confidence in his/her intervention. It is deemed insufficient to just send only the radar's contact track information. The imagery forms a mandatory part of the total information inputs needed by the base operator for an accurate and timely intervention.

BRIEF DESCRIPTION OF THE INVENTION

Object of the Invention

9. The method of sending a plurality of radar images and contact track information as generated by the radar computer to its vessel's on-board navigation computer and base-operated computer at a remote site, for appropriate display, surveillance, navigation, obstacle avoidance and record, collectively referred to as the Radar Tracking Method (hereinafter referred to as "*RTM*"). The invention involves both method and software implementations.

Disclosure of the Invention

10. The invention discloses the method in which a plurality of radar images and contact track information being sent via ship-board network from the *radar computer* to the *USV*'s navigation computer (hereinafter referred to as '*navigation computer*') and over-the-air to a shore base computer (hereinafter referred to as '*base computer*') or multi-base computers for appropriate display, surveillance, navigation, obstacle avoidance and record.

11. In a preferred form as shown in the drawings, the radar antenna first receives the spoke data in one of the angular sweep of the radar antenna and the *radar computer*, based on the strength algorithm, will form the first sectoral radar image and contact echoes information. This is then compared with its existing contact track information list. The contact could be identified as "new" or "existing". Based on the policy and criteria set within the *radar computer*, these contact echoes are numbered and ready to be served to the other concerned computers. Once a complete sweep of the radar antenna is completed, a complete radar image for the particular scan is formed, with its associated contact echo track information.

12. These data are then served to the *USV*'s *radar computer's* fusion server. The fusion server will merge with the other contact track information obtained from, such as, but not limited to, electronic chart information, automatic identification system (AIS), visible contacts from the day cameras, optical contacts from electro-optical (EO) cameras, and manual contacts from base operator, to form a finalised contact track list.

13. The associated radar images and the finalised contact track list are then served by the *radar computer* via the on-board network to the USV's *navigation computer* and via over-the-air to the *base computer*.

14. The base operator, after reviewing the finalised contact track information via a computer display and its current associated radar echo image, would then be able to form a confident and accurate opinion as to whether he/she needs to intervene into the autonomous operation of the *USV* in a correct and timely manner.

BRIEF DESCRIPTION OF THE DRAWINGS

15. In order that this invention may be more readily understood and put into practical effect, reference will now be made to the accompanying drawings that illustrate the preferred embodiment of the invention, and wherein:

FIGURE 1 is a schematic connection diagram representing the Radar Echo Contact Detection and Echo Contact Track Management of the preferred embodiment of the invention.

FIGURE 2 is a schematic block diagram representing the Radar Echo Contact Detection and Echo Contact Track Management of the preferred embodiment of the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

16. An exemplary embodiment of a preferred form of the invention will now be described with reference to FIGURES 1 to 2.

17. **FIGURE 1** shows a schematic connection diagram representing the Method of Radar Echo Contact Detection and Echo Contact Track Management. In the diagram, a single **Radar Antenna 101** is being deployed on–board the *USV*. The radar antenna is connected to its dedicated **Radar Computer with software 103**, via either **NMEA 2000 or Ethernet 102**. The radar antenna shall sweep in an angular manner at a rotational speed of 24 to 48 or any other revolutions per minute, or in any other combinations, providing sectoral contact echoes and imageries to the *radar computer*. Based on a dedicated algorithm, the strength of each contact echo is now analysed and recorded either as “new” or “existing”. These data are then further analysed for further track correlation and reporting.

18. Once the radar antenna completes one all-round scan, the image and the contact track information thus formed are now sent to the **Fusion Server and Client with software 601**, within the *radar computer*. Within the fusion server, the contact track information are further correlated by merging with the other contact track information derived from the other sensors, such as, but not limited to, electronic chart information, automatic identification system (AIS), visible contacts from the day cameras, optical contacts from electro-optical (EO) cameras, and manual contacts from base operator, to form one finalised contact track information.

19. The final complete radar image for one-complete-scan, together with its merged contact track information are then appropriately compressed into manageable sizes and sent via the **Ethernet or WIFI 104** connection to the USV’s dedicated **Navigation Computer with software 203**. The *navigation computer* will then access the **Smart Chart Manager 202** to draw the correct map information and display the contact track information, together with its underlying map charts, onto the *navigation computer*’s display to provide a wholesome picture of the current situation of the *USV*-in-operation. In order to assist the accurate and timely display of these contact track information, additional inputs from the various sensors, such as, but not limited to, the **GPS 204** for providing position, course-over-ground and speed-over-ground, **USV Variables Manager 205** for providing wind speed and direction, rudder position, port and starboard engine revolutions and etc., **Position Manager 206** for providing the most updated smooth current position, **Gyroscope 209** for providing immediate heading, and etc., are used.

20. At exactly the same time, the same imagery and contact track information are sent in duplicate, with encryption, via the **Satellite Comm 207** and/or **Mobile Broadband 208** to the dedicated **Base Computer with software 303** for the benefit of and use by the base operator. In the extended version, the base computer software can accommodate a multi-base operation, where the **multi-base computers with software 302** are deployed.

21. **FIGURE 2** shows a schematic block diagram representing the Method of Radar Echo Contact Detection and Echo Contact Track Management. In the diagram, the method is wholesomely labelled as **The Method 1000**. In the method, a single **Radar Antenna 101** is being deployed on–board the *USV*, but need not be limited to just one radar antenna. The radar antenna is connected to its dedicated **Radar Computer with software 103**, via either NMEA 2000 or

Ethernet. As the *USV* needs to sail in order to receive real data, software testing, training and evaluation can therefore be done using previously collected real data to act as **Simulated Data 407**. Additionally, the operation of the **basic radar functions 408** can also be simulated or for real.

22. Within the *radar computer* 103, the software is separable to 3 parts:

    a. **The Spoke and Image Data Server 401** forms the first part. In this part, the sectoral spoke echo data is first received from the radar antenna and analysed in this spoke and image data server. Based on a dedicated echo strength algorithm and smoothing using, such as, but not limited to, Gaussian blur, the echoes are classified as real or transient (*i.e.*, by calculating the actual total size of the continuous echo thus formed). Only real echoes within the minimum and maximum size are considered. These echoes in turn shall create the actual sectoral imagery. At the same time, inputs from the other sensors, such as, but not limited to, the **Position Manager 206** for providing the most updated smooth current position of the *USV* and **USV Variables Manager 205** for providing wind speed and direction, rudder position, port and starboard engine revolutions and etc., and, **Gyroscope 209** for providing immediate heading, are used.

    b. **The Spoke and Image Data Client 402** forms the second part. In this part, the sectoral spoke echo data as calculated and formed by the spoke data server is then served to whatsoever counterparts, being set up as a client. In this part, any computer wishes to listen to this part of the data information, can set itself up as a client to the server and receive data accordingly.

    c. **The Contact Track Detection Program 403** forms the third and final part. In this part, the spoke data would be analysed as follows:

        (i) **Pre-Data Analysis 501**

            (1) **Measurements**, such as, but not limited to, timestamp of the spoke data, own USV's position and own USV's course-over-ground and speed-over-ground are recorded.

        (ii) **Spoke Data Analysis 502**

            (1) **Measurements**, such as, but not limited to, each of the contacts' echo size, contact's bearing and distance from the USV's position are recorded.

            (2) **Calculations**. Before the measurements can be used to determine contact track information, correction has to be made to the spoke data, such as, but not limited to, the exact time of arrival of the spoke data and its true bearing. With this correction, own USV's position, own USV's course-over-ground and speed-over-ground and for each of the contacts' bearing and distance can now be calculated and determined to a very high degree of accuracy.

            (3) **Data Preparation**. The initial contact echoes are now detected and an initial contact echo list is formed.

        (iii) **Radar Image Analysis 503**

(1) **Compose Image**. Using the original raw spoke data, an initial radar image marked as sample "**Compose Image 5001**" is composed and compressed for one complete and full radar sweep scan.

(2) **Measurements / Calculations**. For each confirmed contact echo, its echo size and echo box orientation, together with own *USV's* position and own *USV's* course-over-ground and speed-over-ground are measured from the radar image and calculated against linear regressions, Kalman filter, tracing forward or backward to arrive at the track identification and contact track information.

(iv) **Finalised Contact Track Information 504** and its correlated compressed radar image are then readied to be sent and served to the **Fusion Server with software 601**.

23. Within the *Fusion Server and Client with software 601*, the software is separable to 3 parts:

a. **Pre-Data Analysis 602** forms the first part. In this part, after the *finalised contact track information 504* and its correlated compressed radar image are being received successfully by the fusion server. Based on the received timestamp, the fusion server will confirm one more time its own *USV's* position, course-over-ground and speed-over-ground. Once confirmed, for each contact, the track identification and contact track information is accepted into its centralised fused contact track list.

b. **Fusion Data Analysis 603** forms the second part. In this part, the track identification and contact track information mentioned in para 24, part a. of this section, are further correlated and finalised by merging with the other contact track information derived from the other sensors, such as, but not limited to, electronic chart information, automatic identification system (AIS), visible contacts from the day cameras, optical contacts from electro-optical (EO) cameras, and manual contacts from base operator, to form one finalised and **complete contact track information 604**.

c. **Fusion Client 605** forms the third and final part. The software shall send all compressed images and finalised and complete Contact Track Information to *USV's* Navigation Program and Base Command and Control Program and other clients.

24. Within the *USV's* Navigation Program and Base Command and Control Program collectively referred to as software "**701**" and software "**702**" respectively, the software is separable to 2 parts:

a. **Display Image and Contact Track Information 703**. When required by the controllers, the *radar image 5001* and/or contact track information can be displayed for decision making. The base operator, in order to intervene in many of the out-of-the-normal situations, requires the *radar computer* to transmit some form of radar sweep data and/or image and contact track information to the base computers in a timely and regular manner, so that the base operator at the base computers is able to correlate its detected radar echoes against the existing contact track information in order to have full confidence in his/her intervention. It is deemed not sufficient to just send only the radar's contact track information. The imagery forms a mandatory part of the total information inputs needed by the base operator for an accurate and timely intervention. It is significant to note that

in many real instances, such as, but not limited to, many big and small vessels are without AIS information. The base operator in order to confidently confirm if the contact track is authentic and this can only be done by seeing the contact track information is accompanied by a real, solid radar echo imagery.

b. **Obstacle Avoidance (OA) 704**. At all times, the USV's navigation and base's command and control programs may conduct obstacle avoidance. This action is normally made in conjunction with the **Smart Chart Manager 202** that provides electronic chart information. The chart information may include, but not limited to, land marks, buoys and beacons, anchorages, soundings, and/or hazardous navigation zones.

INDUSTRIAL APPLICATION

25. It is to be understood that the above embodiment has been provided only by way of exemplification of this invention, and that further modifications and improvements thereto, as would be apparent to persons skilled in the relevant art, are deemed to fall within the broad scope and ambit of the present invention defined in the claims which follow.