Application of Satellite Navigation Techniques for Vessel's Drift Determination in Piloting Areas

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ABSTRACT: The paper deals with use the satellite navigation system for increase safety of navigation in difficult areas. There have been presented an algorithm to ship control procedure during environmental disturbances in narrow passages.

1 INTRODUCTION

There are many advanced modern dynamic positioning and autopilot systems, most of them based on Kalman filtering [1], however these systems usually require multiple sensors that provide parameters with a good accuracy. In specific conditions these measurements are sometimes difficult or impossible to measure or compute. Environmental forces such as waves, wind and current cause the vessel to drift. These forces are usually separated into wave- and low-frequency components [2] and many investigations are devoted for estimating the effects of waves, wind and current forces on a ship motion [6]. Since there are no sensors to measure environmental forces acting on a ship with sufficient accuracy, it is impossible to use feed forward from the environmental disturbances. Thus, it can be assumed for disturbance modeling that environmental forces are constant or at least slowly varying [3]. However the corrections must be implemented to obtain the planned track of a vessel. In presented model the angle of vessel's total drift can be effectively used for true heading correction with a good accuracy. This method can be easy way to correct deviations of the actual vessel trajectory from the planned vessel trajectory.

2 VESSEL'S TOTAL DRIFT DETERMINATION

2.1 True heading determination

To determine the true heading of a ship, a local geographical Earth-fixed frame is used. We assume the initial $A_1(\varphi_1, \lambda_1)$ and next position of a ship $A_2(\varphi_2, \lambda_2)$, obtained from satellite aerials' positions. The true heading TC is calculated from the formula:

$$TC = arctg(\Delta\lambda \cos\varphi_M / \Delta\varphi), \qquad (1)$$

where

$$\Delta\lambda = \lambda_2 - \lambda_1,$$
$$\Delta\varphi = \varphi_2 - \varphi_1,$$
$$\varphi_M = (\varphi_1 + \varphi_2)/2.$$

Other relationship that can be used to determine true heading is:

$$TC = \arccos(\Delta\varphi / d_L),$$

where d_L denotes the main length of base line on board the ship and has been presented in figure 1.
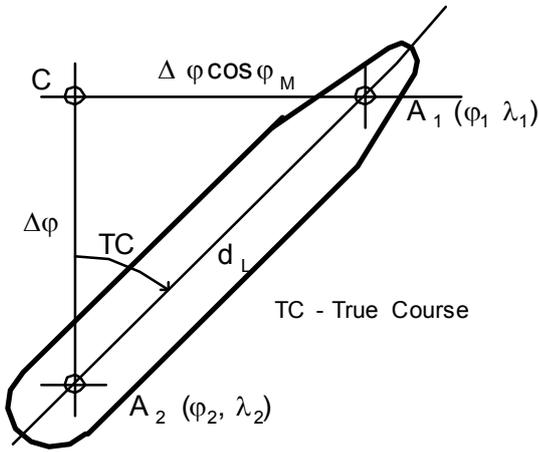
Figure 1. Base line on board the ship using two GPS receivers for true course determination

2.2 Course over ground determination

An important issue of vessels' navigation in restricted areas is the knowledge of course over ground [5].
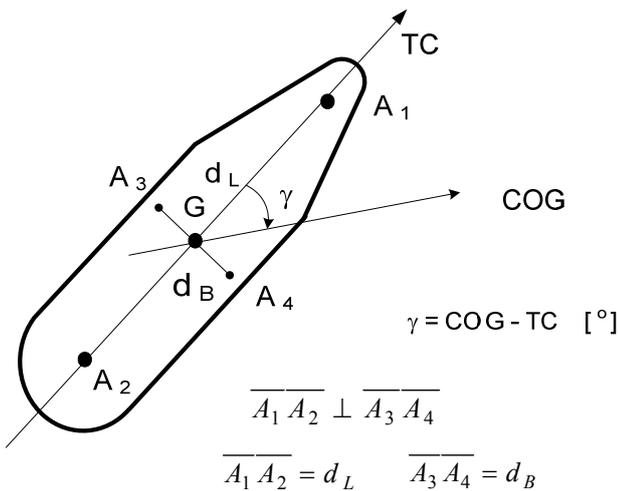

Figure 2. Two bases on board using four GPS receivers for COG determination

To determine the course over ground four antennas of DGPS receivers must by used. The two base lines d_L, d_B are installed on board as presented in figure 2.

For estimation the actual heading and total drift angle during a ship movement four satellite position must be observed. Next we denote by $G_1(\varphi_{G_1}, \lambda_{G_1})$ the fixed position of a ship at moment t_1, and by $G_2(\varphi_{G_2}, \lambda_{G_2})$ the position of a ship after a distance d_G at moment t_2. Time $\Delta t = t_2 - t_1$, can be a step for repeating the procedure in algorithm. Having in disposal four satellite aerials with given positions $A_1(\varphi_1, \lambda_1)$, $A_2(\varphi_2, \lambda_2)$, $A_3(\varphi_3, \lambda_3)$, $A_4(\varphi_4, \lambda_4)$ at moment t_1, we can determine the

fixed position G_1 of a ship as a mean value of aerials' positions:

$$\varphi_{G_1} = (\varphi_1 + \varphi_2 + \varphi_3 + \varphi_4)/4,$$
$$\lambda_{G_1} = (\lambda_1 + \lambda_2 + \lambda_3 + \lambda_4)/4. \qquad (2)$$
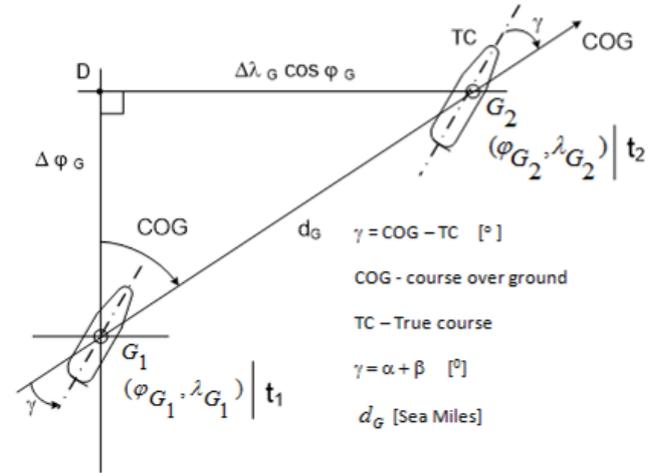

Figure 3. Setting of two fixes G_1 and G_2 to determine course over ground

The vessel's course over ground COG can be determine from formula:

$$COG = \arcsin((\lambda_{G_2} - \lambda_{G_1})\cos\varphi_G / d_G), \qquad (3)$$

or

$$COG = \arccos((\varphi_{G_2} - \varphi_{G_1})/d_G), \qquad (4)$$

where $\varphi_G = (\varphi_{G_1} + \varphi_{G_2})/2$ and distance run between positions G_1, G_2:

$$d_G = \sqrt{[(\lambda_{G_2} - \lambda_{G_1})\cos\varphi_G]^2 + (\varphi_{G_2} - \varphi_{G_1})^2}. \qquad (5)$$

Finally the angle of vessel's total drift is given by formula:

$$\gamma = COG - TC. \qquad (6)$$

3 ALGORITHM FOR VESSEL'S DRIFT CALCULATION

Presented algorithm consists of three parts: the initialization, drift estimation and true heading updating, see figure 4.
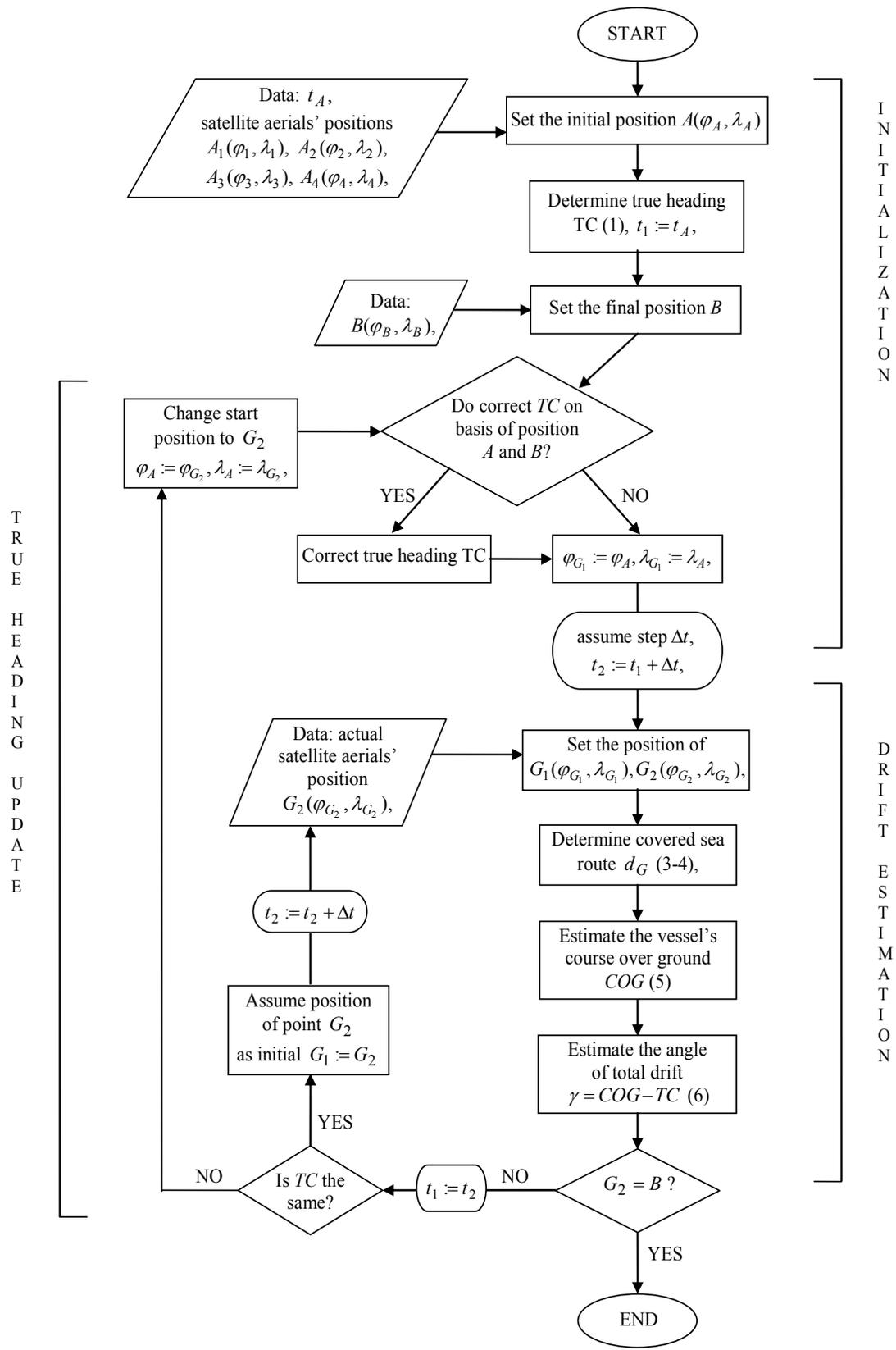
START

INITIALIZATION

Data: t_A, satellite aerials' positions $A_1(\varphi_1,\lambda_1)$, $A_2(\varphi_2,\lambda_2)$, $A_3(\varphi_3,\lambda_3)$, $A_4(\varphi_4,\lambda_4)$,

Set the initial position $A(\varphi_A,\lambda_A)$

Determine true heading TC (1), $t_1 := t_A$,

Data: $B(\varphi_B,\lambda_B)$,

Set the final position B

Do correct TC on basis of position A and B?

YES → Correct true heading TC → $\varphi_{G_1} := \varphi_A$, $\lambda_{G_1} := \lambda_A$,

NO

Change start position to G_2 $\varphi_A := \varphi_{G_2}$, $\lambda_A := \lambda_{G_2}$,

assume step Δt, $t_2 := t_1 + \Delta t$,

TRUE HEADING UPDATE

DRIFT ESTIMATION

Data: actual satellite aerials' position $G_2(\varphi_{G_2},\lambda_{G_2})$,

Set the position of $G_1(\varphi_{G_1},\lambda_{G_1})$, $G_2(\varphi_{G_2},\lambda_{G_2})$,

Determine covered sea route d_G (3-4),

Estimate the vessel's course over ground COG (5)

Estimate the angle of total drift $\gamma = COG - TC$ (6)

$t_2 := t_2 + \Delta t$

Assume position of point G_2 as initial $G_1 := G_2$

YES

Is TC the same?

NO

$t_1 := t_2$

NO

$G_2 = B$?

YES

END

Figure 4. Block diagram for true heading and angle of vessel's total drift calculation

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In the initial part all necessary data should be given i.e. satellite aerials' positions on the ship board at starting moment and final position that is a destination of a vessel. On the basis of these data the true heading is calculated as it has been presented in Section 2. Next the procedure of determining the vessel's course over ground and angle of total drift is repeated in each loop after time step Δt. The process ends after reaching (getting) the destination that is position B. In each step the true heading of a vessel might be corrected taking into account actual vessel's position, destination and estimated angle of total drift. Application is written in Java language using SSJ V2.1.3. Library. The program window for reading initial data is given in figure 5.
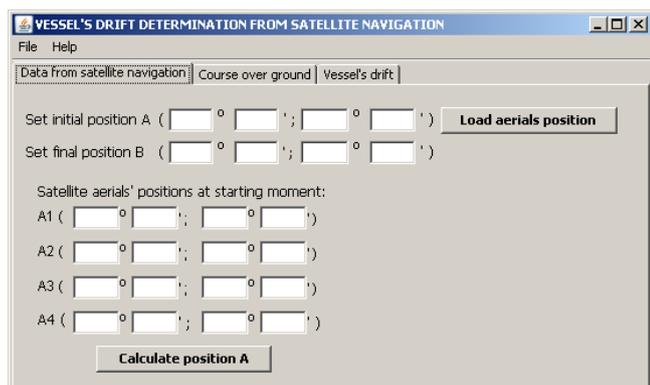

Figure 5. Program window for reading initial data

The initial position A can be counted from satellite aerials' positions that should be loaded from satellite navigation system. The final position B can be given by the user however it is possible to omit it. In that case it is impossible to correct the true heading of a vessel on basis of actual vessel position and destination. The remaining part of the process does not change.

4 CONCLUSION

1 Presented above simple algorithm for continuous monitoring in time the actual heading of a ship movements can be effectively used for asses the course over ground and determine the total drift of the vessel.

2 Designated algorithm provides following functions:
  - monitoring and assessment of navigation processes,
  - presenting current drift of the ship,
  - helping in route determination,
  - supporting navigation decisions.

3 The algorithm is developed to aid the officer on the watch in the process of conducting navigation in restricted waters.

4 Application of presented system will contribute to increase safety on navigation in piloting areas.

5 The accuracy of determining true heading and course over ground depends on accuracy of given aerials' positions. The length bases d_L, d_B used to determine vessel's true heading and drift angel have also influence on computation accuracy [5][7].

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