ABSTRACT: The display mode is intended for facilitation of building strategies for collision avoidance by so-called B-maneuuvres. It can be used in ECDIS, ARPA and the simulator systems. B-maneuuvre includes the segment of deviation at a certain angle from the initial course and at the end of it the segment parallel to the initial way’s line (planned route). The offered mode is based on the use of forbidden domains for B-maneuuvres. These domains allow choosing parameters and beginning moment of B-maneuuvre for collision avoidance with one or a few vessels. The account of presence of navigation hazards at the choice of B-maneuuvre is produced by setting the borders of maximum lateral shifting from planned route. The offered mode enables visual drafting of strategies for collision avoidance with vessels by successive B-maneuuvres. It is possible to use this mode as basis of computer search of strategies for collisions avoidance with a few targets.

1 INTRODUCTION

Forming of a model of environment is one of major tasks of the control systems. This model must adequately reflect an environment, to provide the high level of understanding of situations and serve as a substantial auxiliary mean at the search of decisions. Choosing one such model of environment for different situations of vessels interaction is difficult, because belonging of elements of environment and properties of operating ship to the categories «substantial», «unimportant» changes in them. It is also difficult to get the universal method of decision for preventing collisions. It is better to determine the environment model and methods of decisions as it applies to different situations. Then the choice of strategies of conduct will be simpler, and they – more precise. Therefore the local problem of development mode for presentation situation of vessels interaction and choosing an effective B-maneuuvre for collision avoidance and passing at a safe distance of targets was set.

2 FORBIDDEN DOMAIN FOR B-MANOEUVRE FORMING

It is accepted, that the alterations of course of operating ship are instantaneous. At such condition a B-maneuuvre looks like shown on a Figure 1, where $K$ – planned course of operating ship; $\theta$ – angle of it alteration; $Y$ – lateral distance from initial line of way to the operating ship at the end of deviation; $S$ – length of deviation segment; $C_H$ и $C_K$ – points of course alteration. Course for deviation to starboard ($K+\theta$) is designated $K_S$, to port ($K-\theta$) – as $K_P$. An angle $\theta$ for collisions avoidance can undertake from 20$^0$ to 150$^0$, and for returning to the initial line of way after passing vessels – from 10$^0$ to 45$^0$.

Figure 1. Parameters of B-maneuuvre

Current positions of operating ship and scanned vessel (target) is shown below on Figure 2 by points C and Z. Taking into account presents of navigational hazards and necessity to determine only dander targets within navigable area the zone of manoeuvres and motion (ZMM) of operating ship is set (maximum allowable track margin for current leg). It is determined by width ($Y_{DS}$, $Y_{DP}$) of starboard and port lanes for shifting of operating ship at B-maneuuvres.

Beginning of lane of possible shifting to starboard forms a segment $CQ$ on the course $K_S=K+\theta_S$
(Fig. 2), where $\theta_S = \text{set alteration of initial course for B-maneuvers to starboard}$. The butt end segment of port lane is directed parallel a course $K_p = K - \theta_p$ ($\theta_p = \text{set alteration of initial course to port}$). The values of $\theta_S$ and $\theta_p$ can be both identical and different. The current position $C$ of operating ship is considered as the appointed element of both lanes.

Principle of construction of forbidden domain (FD) is characterized in starboard lane on a Figure 2 (Vagushchenko, A.L. 2008), where $K$, $V$ = planned course and speed of operating ship; $K_Z$, $V_Z$ = course and speed of target; $K' S$ = course and speed of operating ship in relation to a target at true courses $K$, $K_S$ of operating ship; $D_Z$ = safe limit of distance between ships; $A_1$, $A_2$ = points of turn from a course $K$ to the course $K_S$ for passing a target at distance $D_Z$; $B_1$, $B_2$ = points of returning from a course $K_S$ to the former course $K$ for passing a target at distance $D_Z$;

$mnpqer$ = forbidden domain;

$O$, $A_0$, $B_0$ = the FD center and points of turn from a course $K$ to the course $K_S$ and returning from a course $K_S$ to the former course $K$ for CPA=0;

$A'_0$, $A'_1$, $A'_2$ and $B'_0$, $B'_1$, $B'_2$ = points on the lines of relative motion of operating ship, proper to the points $A_0$, $A_1$, $A_2$ and $B_0$, $B_1$, $B_2$;

$\Delta Y$ - interval of lateral deviations from the planned way which provide close-quarters situation with a target at B-maneuvers.

Distances $S_{AI}$ and $S_{BI}$ ($J=0, 1, 2$) from a current place $C$ of operating ship to the points $A_0$, $A_1$, $A_2$ and $B_0$, $B_1$, $B_2$ are determined on intervals of time $t_{AI}$ and $t_{BI}$ for arrival in these points. These intervals are calculated by values of $S'_{AI}$ and $S'_{BI}$ ($CA'_0$, $CA'_1$, $CA'_2$ and $CB'_0$, $CB'_1$, $CB'_2$) and $V'$, $V_S'$.

$$t_{AI} = S'_{AI} / V'$$

$$t_{BI} = S'_{BI} / V_S'$$

$$S_{AI} = V \cdot t_{AI}$$

$$S_{BI} = V \cdot t_{BI}$$

3 USE THE DISPLAY MODE FOR CHOOSING MANOEUVRES FOR COLLISION AVOIDANCE

The category of targets is determined on the location FD in relation to the ZMM borders (Fig. 3). If a target by transponder AIS reported the way points of the route or informed about the set manoeuvre, then an operating ship gets FD of this target taking into account accepted information (target 5, Fig. 3). The probability of possible maneuvering of danger or obstacle vessels can be determined by the expert system (not presented in this paper). In this case the mode of situation can be added with the second FD for this target, proper to possible new course (target 1, Fig. 3). These two FD of target 1 allow forming the incorporated forbidden domain taking into account a possible manoeuvre of target.

Fig. 3. Situation presentation scheme

The B-maneuver for collision avoidance is determined visually on the reflection situation on the screen. The B-maneuver is set by pointing the cursor, for example, on point $C_K$. The trajectory of future motion of operating ship would not cross the forbidden domains. Point $C_E$ marked the end of B-maneuver, after which a dangerous ship can be considered finally passed. By a criterion for the choice of B-maneuver it is possible to take minimum distance of shifting ($Y$) from the planned line on condition that the degree of risk of collision with all targets will not exceed the legitimate value at the point $C_E$ and manoeuvre will not conflict with
ColRegs.

The next action is then planned. Depending on the circumstances one of three actions of operating vessel gets out after the first B-manoeuvre: motion along a new line parallel to the planned line (Fig. 4,a); returning on the planned line by B-manoeuvre (Fig. 4,b); proceeding by the course to next way point (Fig. 4,c). The borders of ZMM can be corrected accordingly, if necessary.

After this the point $C_{E1}$ is undertaken as appointed element for new ZMM. In this ZMM forbidden domains are determined on the prognosis of motion of operating ship and targets. Similar to finding the first manoeuvre, the second and the following ones are planned, if necessary. The point $C_{E1}$ determines ZMM until operating ship will not come to this point, whereupon the current position of operating ship becomes the appointed element of this zone.

While searching B-manoeuvres at the beginning by default the values $\theta_S$ and $\theta_P$ are undertaken as the best from point of providing as noticeable a manoeuvre and prevention of losses of underway time ($\theta\approx35^\circ$). When returning to the former line after deviation (Fig. 4,b), the value $\theta$ can be taken less.

If it appears that at the chosen values of parameters $\theta_S$, $\theta_P$, $D_Z$ a safe manoeuvre does not exist, it is searched with other values -values of parameters $\theta_S$, $\theta_P$ at the search are increased, and a value of parameter $D_Z$ is decrease till the least allows value.

4 CONCLUSION

The offered mode for situations presentation simplifies the choice of manoeuvres by a course change for collision avoidance with a few vessels in open sea and in the confined waters. Advantages of this mode are:

- immobility of the domains in relation to ground, that allows to define manoeuvres for collision avoidance with mobile objects as with immobile;
- simplicity of account of navigation hazards by setting the borders of lateral shifting from planned way;
- possibility to form a strategy for collisions avoidance with a few targets by successive B-manoeuvres;
- possibility to use this mode as basis of computer search of strategies for collision avoidance in any situations.

REFERENCES